PRACTICAL LAWN CRAFT

by

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Foreword

The agricultural sward and the turf of well-kept lawns are strikingly different from each other, and the proper upkeep of each demands very different treatment. The agricultural scientist concerned with grass land has for long been interested in turf, and indeed modern turf research owes much to earlier agronomists. Turf, however, offers so many problems of its own that the agronomist who owes prime allegiance to agriculture could not legitimately devote sufficient attention to their solution, and it is in every way right and proper that the sports and other interests making demands on turf should sponsor the necessary researches.

The ancient game of golf makes calls on turf of the highest quality, and the greatest credit is due to golfers that they have been the first to set up research stations devoted solely to the study of lawns and greens.

The Station at St. Ives was founded in 1929, and under the able direction of Mr. Dawson has achieved a world-wide reputation, and is a model of what a turf research station should be.

Mr. Dawson has written a most valuable and exhaustive book on the subject of turf, covering the whole field from golf to cricket, from cricket to football, and including polo grounds, racecourses and aerodromes. Every one of these makes demands on turf different from the other, and all quite different from those of agriculture.

Although most game players, and most of those who maintain garden lawns, now realize that the care of a lawn consists of much more than mowing and rolling, it will come as a surprise to many that the subject of proper treatment is as involved and as difficult as it is. Mr. Dawson has admirably covered the

whole field, and as well as drawing upon the results of the researches at his own station has quoted copiously from those conducted elsewhere.

The book is excellently arranged, and will serve as an invaluable guide and reference book alike to professional greenkeepers and groundsmen and to amateurs.

In my experience the greatest mistakes are frequently made in the matter of cutting, watering, and rolling, and in the time of applying fertilizers; everybody reading the following chapters will be made fully aware of the pitfalls.

Lawns and lawn games are of the very essence of Britain and of the British peoples, and now that the numbers who actually enjoy, as well as those who watch, such games is so rapidly increasing there could be no more opportune book than this. It is in fact a worthy book on a worthy subject, and one of real national importance.

I personally am under a special debt of gratitude to Mr. Dawson and his research station, for there is no reason now why I should be even expected to know or to advise about turf, and all such correspondence as comes my way I have for long discreetly directed to St. Ives. The advent of Mr. Dawson's book will mean that all inquiries that have been inadvertently addressed to the agricultural research stations will automatically go to St. Ives.

R. G. STAPLEDON.

AGRICULTURAL BUILDINGS,
ABERYSTWYTH.
April, 1938

Author's Prefaces

To the First Edition

It may appear to be inexcusable at first sight to add to the existing stock of printed matter on turf upkeep, but the present purpose is to examine the subject from the scientific angle. The wider interest shown to-day in turf culture and the desire for advice demand a treatise designed to supply factual information of a reliable nature. Further, recent advances in knowledge of turf grasses, pest and weed control, to mention but a few subjects, demand exposition.

It is almost true to say that there are as many conflicting views on lawn upkeep as there are lawn owners. Everyone is an expert, and so he may be in so far as his own particular patch is concerned, but the author's aim has been to distinguish supposition from certainty and to provide information based on experiment or well-founded practical experience. It will be obvious that only broad guiding principles can possibly be outlined in a book of this kind. There can be no "cut and dried" system of turf upkeep, since there are so many different conditions and requirements, but detailed application of the principles is necessary to give the best results. Just as the physician cannot prescribe text-book advice to all patients, but must draw upon his experience as a practising doctor, so each turf area must be treated on its own merits with due regard to all the relevant factors.

There is a tendency among amateurs to think of the lawn only in terms of mowing and perhaps manuring, forgetting the biological processes involved and the fact that a lawn is composed of living units subject to inter-reactions and to the influence of outside factors. An aim has been to demonstrate that good upkeep involves something more than mowing or

manuring. Further, many lawn owners labour to produce a fine sward from one composed of unsuitable species or strains, but if the right grasses are present each maintenance operation should contribute its quota to betterment. The importance of strain has been elaborated.

The information in this book is based largely upon the experiments carried out by the author and his colleagues at the St. Ives Research Station since 1929, but references have also been included to the published papers (mainly scientific) of others who have worked on turf problems.

To be called upon to advise from every angle upon lawns, golf courses, and sports grounds of all kinds, scattered throughout Great Britain and parts of the Continent, has provided unique opportunities for studying turf maintenance under very varied conditions. This practical experience has been freely drawn upon in the preparation of the book.

The chapters upon sports ground upkeep, Section IV, are necessarily short because much of the information given in the first three sections of the book is capable of application to all types of turf.

The author makes grateful acknowledgment of the assistance willingly rendered and the suggestions offered by his colleagues during the preparation of the manuscript. He is indebted to Mr. R. B. Ferro, Chief Advisory Officer at St. Ives Research Station, who has read the manuscript and made valuable suggestions on both practical and scientific sides. The author also thanks friends in the seed and fertilizer trades, who have always been ready to answer the points put before them.

Finally, the author wishes to record his indebtedness to Professor R. G. Stapledon for contributing a foreword, and for much helpful advice in connexion with the turf investigations at St. Ives.

R. B. D.

BINGLEY.

April, 1938

To the Revised Edition

During the war years ploughing-up of sports grounds, golf courses and the digging up of lawns in the interests of increased crop production has been extensive. Further, many of the turf areas spared by the plough and spade have suffered a decline in quality due to the scarcity of labour, materials and even funds. Thoughts are now turning, however, to peaceful pursuits, and the time is growing nearer when restoration of cultivated land to its original purpose, as well as the renovation of neglected turf, will become practicable. The appreciative reception of the first edition leads to the belief that the re-appearance of this book will enable it to be of continued service when the process of restoration and renovation starts.

The original purpose of the book has been adhered to; indeed, with the exception of minor corrections and some additions, the book is practically a reprint of the first edition. Some of the additions comprise new information published since the date of the first edition or based on trials at that time incomplete. Further information on mowing technique has been included, whilst a new appendix deals with adjustment and maintenance of mowers. Additions have also been made to the section dealing with turf in other countries.

R. B. D.

Bingley.
October, 1944.

NOTE: Some of the materials referred to in the text are not at present available owing to war conditions and the manufacture of new lawn accessories is severely curtailed. Where prices are quoted they are those prevailing prior to the war.

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SECTION I

INTRODUCTORY

Chapter One

The Lawn as a Feature of Home and Garden

From the earliest times an adequate, well-maintained lawn has been an essential and basic feature of the gardens of this country. Indeed, our lawns and sports grounds are as characteristic of our national life as our homes and firesides. Wherever men of these islands have made their homes, even in the most inhospitable parts of the earth, they have striven to produce and maintain lawns as an unconscious link with their Homeland.

The amenity that a lawn confers upon a home is well recognized by nearly all garden and home lovers. It provides a feeling of restfulness and is a foil to the flower display. Further, it has an æsthetic value in making the garden look better, and the peaceful, soothing effect of green coolness on a good, well-designed lawn, is perhaps the main delight.

To be a success, however, the lawn must be related to the design of the garden and must conform to its general contours. A well-planned lawn should be the result of a definite mental picture, and the aim should be to produce something that is at the same time beautiful and useful, yet avoiding extreme plainness as well as extreme ornamentation. One American writer upon lawns has rather aptly described the lawn as "the carpet of the outdoor living-room". The quality of that carpet is dependent in large measure upon colour, texture, density of pile, and uniformity, as well as upon its outlines and its relationship to the other furnishings of the outdoor room.

It is not necessary to have a large piece of land to produce a lawn—even the tiniest area can have its plot of grass, and perhaps one of the most striking features of modern housing estates

is the way in which almost every householder endeavours to provide at least a small grass plot, even if some other feature be omitted. Unfortunately many of these grass plots are of poor quality, though there is no reason why they should not be greatly improved with a little extra endeavour and with very small extra expense. For the lack of a little well-directed advice, especially at the start, the result is too often mediocre.

Whilst we, in this country, are blessed with a climate that is favourable to the production of grass, we do not always take advantage of our good fortune: although the high reputation enjoyed by our turf is well deserved in many instances, yet sad to say there exist countless lawns that are a disgrace to any country. Even the college lawns of the older universities with their high reputation for beauty, are more to be commended by their architectural surroundings and their associations than the quality of the turf, which is often much poorer than one finds on a working-man's bowling green or on the putting greens of an average golf course. In spite of their blemishes, however, our lawns are invariably the envy of visitors from abroad.

An area of turf in a garden may well determine the character of that garden, but it may equally be said that the quality of turf on a sports lawn will make or mar the game for which it is prepared. Intensive training and better accessories will no doubt improve one's game, but this advantage is quickly lost unless there are corresponding developments in the quality and suitability of the turf. Of what use are the modern refinements of say the lawn-tennis ball and golf ball, or the present-day golf club and tennis racquet, if the advantage is largely nullified by the poor condition of the turf sward? It is perhaps not too much to say that if we are to retain our national position in sport we must in future pay greater attention to the improvement of our sports turf. In many cases the poorness of the turf can largely be attributed to incorrect balance in club expenditure, too much money being spent on unnecessary apparatus, patent mixtures or an imposing club-room and too little on employment of adequately trained ground staff and the purchase of essential greenkeeping materials.

Recent increases in the number of sports grounds and recreation grounds, often as a result of the work of the National

Playing Fields Association, or through an enlivened consciousness of local authorities to the provision of turf for games and ornament, are leading to a greater interest in turf upkeep, especially from the scientific angle. Much more remains to be done in the provision of reasonable recreational facilities for both sexes, not only in Urban areas but in the countryside, where information in the hands of the National Playing Fields Association shows that in some Counties not more than 10 per cent. of Rural Parishes have made any provision at all for playing fields.

The improvement of lawn and sports turf in this country is a matter of national prestige, and it is to be hoped that the wider interest at present showing, will lead to the elimination of many of those inferior turf swards that are so lacking in quality and "character".

Chapter Two

The History of the Lawn and the Scientific Study of Turf

Lawns, like most garden features, have been the subject of evolution and have suffered changes dictated by fashion, yet they have invariably emerged little changed and defiant to maintain their own unrivalled position in garden architecture. Although it is probable that lawns (possibly made of plants other than grasses) formed a part of classical gardens, real knowledge only becomes available in the literature of mediæval times. All lawn lovers should be grateful to Miss Eleanour Sinclair Rohde, who has searched the literature and brought together the early references to lawns in a fascinating article [1] * that deserves to be much better known. Thus it appears from Boccaccio's *Decameron* and a later edition of the thirteenth-century *Romance of the Rose* that the mediæval lawn was not the pure grass sward we strive for to-day but an imitation of a natural meadow "starred with a thousand flowers". In the old monastic cloisters, also, the central green plot was planted with flowers and divided into quarters by paths intersecting in the centre—an arrangement, as Miss Rohde points out, suggestive of the rectangular garden plots portrayed in Persian garden-carpets. One constant feature of the mediæval garden was the orchard, carpeted with short grass and flowering plants, whilst another was the turf-topped seat planted with flowers, and built around trees or enclosed in an arbour built at the side of the lawn.

In the sixteenth century the tendency was for the garden to

[1] Rohde, Eleanour Sinclair: *Nineteenth Century and After*, 1928, CIV, 200.

* Numbers appearing in the text refer to the papers or reports consulted which are given at the foot of the appropriate page and/or in the bibliography at p. 281.

increase in size and to comprise separate "gardens within a garden" and including an orchard, a knot-garden, a herb-garden, a physic-garden, and a bowling green, and contemporary descriptions of the preparation of the turf are in existence. Turfed paths or walks were also a feature of the gardens of this period, but the lawns and walks were not always made of turf. Thus John Evelyn, born 1620, gave in his diary (*Kalendarium Hortense*) under October, instructions for the maintenance of camomile lawns, and other garden books of this period make a point of referring to this plant. Areas of it still survive in the lawns of some of the royal parks, thus forming an interesting link with the past. It has been suggested that the turf upon which Drake played the historic game of bowls on the eve of the appearance of the Armada was not comprised of grass but of camomile.

It was not, however, until the eighteenth century that the lawn really came into its own and every garden book of the period treated the subject. The ruling fashion then was to provide a large expanse of closely-tended grass unadorned by flower beds or shrubs and falling in sweeps and undulations about the house. Round about this time, too, the garden experts began to comment upon the difficulties of obtaining good seed, and Miss Rohde in her history of the lawn quotes one anonymous author as directing that on no account should hay seeds be used for sowing lawns and that seeds for this purpose should always be obtained from "the grass of clean upland pastures". One would like to have honoured the name of this unknown author, for he must surely have been the first to appreciate the value of turf made from the fine-leaved grasses, the bents, fescues, and wavy hairs such as one would expect to find in a pasture so described and where the weed flora would be much reduced.

The antiquity of the bowling green and the fact that bowls was played in the thirteenth century are well established, and whilst the mediæval lawn was the forerunner of the present-day garden lawn, the original bowling lawn was the precursor of the modern greens, and indeed of all the turf areas that, with their several requirements, we need to-day for our wider range of outdoor sports. A turf area that is required for purely ornamental purposes or for outdoor games, must rightly be classified as a lawn, and will be subject to the same general principles of management.

Turf upkeep is among the oldest of arts, but has depended upon scraps of knowledge handed on from father to son, and perhaps often forgotten through the passage of time or by being buried with the dead. In fact, management was conducted by rule of thumb, and whilst a certain set of operations produced in some instances tolerably good results the operator was unable to explain the reasons for carrying them out. The results when positive were only satisfactory through the fortunate coincidence of circumstances—in other words, to good luck.

Perhaps the most epoch-making event in the history of the lawn was the invention of the rotary mower, the principle of which appears to have first occurred to one Edwin Budding in 1830. The first petrol motor-driven lawn mower was produced in 1902. The rotary mower marks the inception of modern turf management, and whilst it made fine lawns generally possible it also introduced a new factor as far as the composition of the turf was concerned, and further discussion of this topic will be introduced later.

The more recent developments in the upkeep of lawns are mainly concerned with improved methods of maintenance, better seeds, better tools, and better materials, and with the more intensive study and application of scientific methods to the subject. It may not be without interest to review briefly the progress that has been made in the direction of scientific investigation, though unfortunately this country has lagged behind others in the critical study of turf upkeep or greenkeeping, as one should describe the science of managing turf.

The first experiments with turf grasses appear to have been carried out in the Olcott turf gardens, Connecticut, in 1885, and were continued until the death of J. B. Olcott in 1910.[2] His aim was to search for species and types of grasses that approached his ideal of perfection, and to this end he selected about 500 strains from some thousands of plants and multiplied his stock of many of these strains so as to give comparative turf plots. It is significant that he came to the conclusion that the best types of grasses for lawns were to be found in the genera *Agrostis* and *Festuca*, among which groups work is still being done to-day. Olcott invariably referred to the upkeep of turf as "grass-gardening" and not greenkeeping, which term appears

[2] Olcott, J. B.: *14th Report of Connecticut Agric. Expt. Station*, 1890.

to have come later and doubtless owes its origin to the "keeping of the green" for the game of golf.

The next stage in the experimental study of turf took place in the United States with the setting up of experiments in 1890 at the Rhode Island State College of Agriculture. The plot trials at this Institute were extended in 1905 and yielded valuable information that has proved the starting-point for many turf gardens and new investigations.

Largely as a result of the enthusiasm of Dr. Charles V. Piper and Dr. R. A. Oakley, of the United States Department of Agriculture, experimental work and demonstration plots gradually increased until almost every State College of Agriculture had its demonstration turf garden. In 1920 the United States Golf Association established its "Green Section", comprising both research and advisory branches. In their experiment ground at Arlington, near Washington, the study of turf was mainly directed towards the special requirements of the game of golf.

Since that time schemes for the scientific study of fine swards, as distinct from agricultural grass land, have steadily increased, and in this country the credit of suggesting that research work should be devoted to the science of greenkeeping must be given to the Green Committee of the Royal & Ancient Golf Club. In 1924 this Committee convened a meeting of club representatives, which was unanimous in its desire that the matter of research should be further investigated. Unfortunately, a subsequent appeal to the clubs for the necessary funds met with insufficient promises of support, and it was not until 1928, when, at the request of the Royal & Ancient Golf Club, the British Golf Unions' Joint Advisory Council, a body representing the National Golf Unions of England, Scotland, Ireland, and Wales, took up the question that any further progress in the matter of a research scheme was made. A further effort was made to enlist the support of the clubs, and in 1929 it was possible to pass a resolution setting up a Board of Greenkeeping Research in the knowledge that all the National Golf Unions had guaranteed their quota of money.

Following this was established a research station and experiment ground on the St. Ives estate at Bingley in Yorkshire, which has come to be known as the centre for greenkeeping research and advice in this country. The enthusiasm of Mr.

Norman Hackett, who had been closely associated with golf greenkeeping for many years, was a major factor in obtaining the support of the clubs and emphasizing the need for experimental work. The main experiments are laid out in old park land at 600 ft. elevation, with various soils and other altitudes available. In constitution the organization of this scheme is more closely analogous to an industrial research scheme without State support, and from which subscribers expect certain very definite benefits. Since 1929 series of experiments in turf upkeep have been in progress and continue to yield valuable results.

In other countries the development of greenkeeping investigations has followed parallel lines, and in New Zealand in 1932 there was set up a Board of Greenkeeping Research, maintained by the golf clubs, and the experiments are following very closely the lines of those in progress at Bingley. In Australia, also, a number of States have started experimental work—for example, New South Wales in 1932, Queensland in 1935, and the latest recruit is the Victorian Golf Association, which set up a research section in 1936. In South Africa the pioneer work is very largely associated with the name of Dr. C. M. Murray [3] of Capetown. It was in 1904 that Dr. Murray first took an interest in the development of greenkeeping, and by the end of 1906 had established a complete series of grass greens at the Royal Cape Golf Course. Previous to this few greens in South Africa were of grass, though some had been put down to grass at Durban as early as 1891 or 1892. In the Transvaal, the first South African Golf Championship was played on grass greens in 1909.

Turf research work in South Africa is in progress, and a scheme similar to that in Britain and New Zealand is now being developed.

Bulletins are issued by the Research Boards or Sections in Great Britain, New Zealand, New South Wales, Queensland, Victoria, and U.S.A., and articles on turf establishment and upkeep in Canada, India, South Africa, and the Federated Malay States have also appeared. Reference will be made later to a selection of the literature. It is probably true to say that in the United States of America nearly as much attention has been paid to lawns as to grass land, and a valuable literature has been built up.

[3] Murray, C. M.: *Greenkeeping in South Africa*, 1932.

One significant fact emerges from a consideration of the history of investigational work, and that is the part played by the Golf Unions and Associations in setting up their own research departments, and further that very little scientific work directly bearing on greenkeeping has been carried out by agricultural colleges and institutes. In at least five countries the initiative has been left to the golfing organizations or individual golfers.

The conduction of research on fine turf in so many countries indicates a world-wide desire for reliable information on turf matters, and the present interchange of literature and ideas between the various research organizations is found mutually helpful. In greenkeeping, the habitat should be more or less under strict control, and the requisites being so similar the findings of greenkeeping researches should have a wider application than, say, the findings of grass-land investigations. Much of the findings in one district or even country can be applied to another district or country where similar climatic conditions obtain. Thus the same general lines of earthworm control, insect and fungal control, the same manurial treatments, the same cutting treatments, the same methods of soil sterilization, should be almost equally applicable wherever applied, though small local refinements may be necessary. Obviously, for instance, a ribwort plantain in New Zealand and another one in England will react to weed killing in like measure, and the same may be said of many other operations, though of course extreme climatic conditions will have their effects in determining the degree of, say, fungal infection and thus of the amount of fungicide required. The amount of money available for purchase of materials and employment of an adequate labour force for general maintenance will often determine differences in the quality of turf to a greater extent than will any inherent differences in the soil or the climate.

Chapter Three

Good and Bad Lawns

he **Causes of Bad Lawns.** A brief consideration of the causes of imperfect lawns is a necessary prelude to the subject of establishing a new lawn and maintaining or renovating an area that has been in existence for some time. Experience shows that very often the lawn owner, especially if he be an amateur, expends countless hours of toil upon his garden lawn attempting to produce a satisfactory sward. If, in spite of these efforts, the results are bad then the conclusion is often reached that the failure is due to infertile soil or some peculiarity that makes it unsuitable for lawn purposes. It may also be argued that the local climate is such that it is unsuited for growing turf; yet, the desirable turf grasses are found growing naturally in soil of low fertility and also at high altitudes or in exposed positions where conditions are anything but ideal or favourable to good growth. Failure to produce the desired result may therefore be attributed more probably to some other cause or group of causes counteracting the work and so operating to produce the poor result.

With new lawns, failure to attain success is generally due to early mistakes that may be enumerated as follows: (1) Cheap or hasty construction of the site; (2) insufficient or incorrect preparation of the top-soil for the reception of the grass; (3) the sowing of impure seed, or seed of low germinating capacity, or even seed of species more suitable for the production of a pasture or meadow than a fine sward; (4) uneven sowing; (5) when the lawn is sodded and not sown, the selection of turf containing the wrong grasses; and (6) in a sodded lawn, failure to lay the turves uniformly. Of the above perhaps the commonest mistake is undue haste, which is wasteful and more expensive in the long

run. The lawn owner who has failed to observe the rules in establishing his turf thus spends his time in trying to put things right rather than in well-directed work in improving the sward or maintaining it in good condition. (See Figs. 1 and 2.)

When lawns have been longer established the causes of failure lie in neglect and mismanagement, the latter including (1) insufficient or wrong manuring; (2) abuse of the roller; (3) the use of a lawn mower that is old or ill-set, or even too heavy; (4) failure to use the mower sufficiently often to obtain the desired uniformity. Established lawns are often unsatisfactory owing to excessive wear and tear, and if the area is small this is apt to be a serious drawback to improvement, but general neglect of the turf is usually found to be the cause of failure. The effects of wrong treatment and neglect show themselves in a turf that is sparse, containing other than dwarf-growing grasses, a raggy surface, sharp undulations that skin with the mower, an extensive weed population, moss invasion, water-logging, and very often a slimy sticky surface that is unsuitable for the production of any growth except green algæ or even liverworts.

Perhaps one of the chief reasons for poor lawns is the failure of lawn owners to realize that turf production and maintenance are exacting and require just as much work, if not more, than any other branch of gardening practice. Very often one finds that a glorious display of bloom in a garden is accompanied by an execrable area of turf. This is a pity—yet such a lawn may have been regularly mown and occasionally rolled, though such treatment alone is not sufficient to produce a pleasing sward.

Whilst there is to-day an undoubted increase in lawn-mindedness and a higher standard of turf requirement, very few people realize that the time factor is so important and that 70 to 80 per cent of the cost of producing a first-class lawn can be put down to labour. The amateur often wonders why a monthly roll and a fortnightly mow fail to give as good a result as obtained at his local bowling green or on the greens of the golf course of which he is a member. It should be remembered that the results on these two classes of turf have not been produced by haphazard attention, but are due to unremitting care and to a higher expenditure upon the sward than the amateur will give. Further, the results follow very careful study and attention to details. This difference may readily be made clear by quoting some figures from golf-course upkeep. Thus, a club of first-class

standard holding about 120 acres of land, may spend, say, £20 per acre on general maintenance, but most of the intensive work is accorded to some $2\frac{1}{2}$ to 3 acres of putting-green surface and actually about one-third of the total annual cost of upkeep on the course may be allotted to the production of the turf on the greens. Perhaps this will serve to bring home the point about expenditure.

The Ideal Lawn. In some instances the owners of neglected lawns are fortunate in having associated with weeds a desirable grass species that will respond readily to treatment. On the other hand, the lawn may have been established with unsuitable grasses and then become invaded by weeds, or it may be afflicted by other complaints. A decision must therefore be reached as to whether it is worth while endeavouring to renovate the lawn or whether it will be easier in the long run to make a fresh start and to establish an entirely new turf from seed or sods. Perhaps a consideration of what constitutes an ideal lawn will assist in coming to a decision on this matter.

Looking at the ideal ornamental lawn from the turf aspect, and not from its general lay-out in conjunction with other garden features, it should first of all be free from weeds. It should also be uniform in colour and provide a true surface. Though the lawn may only be required for ornament and not for putting, trueness of surface is still required because without it close regular mowing is not possible, so that uniform density, texture and colour cannot be attained. If the herbage consists of several species of grass they should be intimately mixed and should not be in patches. Further, the soil should be free from earthworms because the casts thrown on to the surface upset the trueness, lead to caking of the surface, and are favourable to weed invasion. The ideal lawn should not only look well when closely examined, and provide a firm yet soft resilient sward to the foot, but it should provide a satisfactory appearance when viewed from a distance. The lawn should also be reasonably drought-resistant though during severe drought it may become necessary to apply water artificially. In addition, the turf should retain its colour, density, and uniformity to a marked degree throughout the winter months, and should be free from disease at all times.

The aim in lawn upkeep should be to produce a turf that gives satisfaction and pleasure throughout twelve months of the year,

and the attainment of this ideal is not easy. A near approach to the ideal can, however, be attained by patience and by attention to detailed treatment, as has been found on many golf greens where the putting surfaces are playable for 365 days in the year and yet retain their surface and much of their general excellence during the winter. The exacting conditions required on a putting-green are, of course, much greater than those on the ornamental lawn; for one thing the cutting required is keener and any small irregularities of the surface must be eliminated, or putting cannot be accurate. As the conditions to be satisfied on ornamental lawns are less exacting than on a putting green, all-the-year-round excellence should be more easy of attainment, but will involve regular and systematic attention, which should be related to weather and seasonal conditions. As the golf greenkeeper finds early in his career, all treatments must be carried out with as little inconvenience and spoiling of the appearance and surface as possible.

The lawn owner, unlike the farmer, is not concerned with the production of a big bulk of leafage, or with the palatability of the grass he produces; in fact, the grasses (bents, fescues, and meadow-grasses) normally found on good lawns are those that are of least value to the stock farmer and that he generally endeavours to eradicate from his pastures. Similarly, the presence of wild white clover and perennial rye-grass on a lawn is undesirable, although these two species are the stand-by of the grazier. Even the earthworm, the friend and cultivator for the farmer, cannot be tolerated for long on a lawn. Constant mowing is also necessary so that any period of rest or laying up that the farmer's pasture enjoys through the removal of the stock, is not easy under turf conditions. Strains or species of grass that are markedly perennial and strongly aggressive, must be present if the lawn is to withstand constant mowing, and coarser-leaved grasses like Yorkshire fog and creeping soft-grass should be absent.

The conditions required for an ideal lawn are thus very exacting, and one result of this is that the botanical composition of lawns is restricted as regards both the weed and grass species found in them. In this connexion it is seldom realized that the rotary mower is one of the most potent factors in turf upkeep because it shows no selectivity, like the grazing of the farmer's stock, but defoliates all species of grass or weed that are not

adapted to growing very closely adpressed to the ground. The number of grasses able to withstand keen mowing and yet remain persistent is strictly limited, and while further reference will be made to this point in another chapter, the amateur must realize at this point that the mowing machine must be carefully managed, and that it is a factor leading to certain results and so necessitates other auxiliary treatments to help maintain the turf.

Whilst most of the above remarks apply in particular to the ornamental or private lawn, it may be taken that they apply in general to turf for sport, though each class of sports turf must be considered in relation to the game for which it is intended. Hard and fast rules are impossible. This may be illustrated by the following example. On golf greens weedlessness is the ideal, but on fairways, complete freedom from weeds is not so essential though it is nevertheless desirable. There are, however, on golf fairways, certain weeds that are harmless and that it is not necessary to take special steps to control. Thus, if thyme is extensively present among the grass of a golf fairway, not only does it form an essential part of the turf, but, when flowering, it provides a wonderful carpet of colour, so that for both reasons attempts at eradication would be unwarranted. The same consideration applies to heather which on moorland golf courses provides a valued feature. So long as they do not become excessive woodrush, heath bedstraw and ladies' bedstraw form useful constituents of acid turf on golf fairways. The provision of suitable turf for each sport will be dealt with under the appropriate section, but the above general points about the ideal sward and the causes of bad lawns must be borne in mind throughout.

Chapter Four

he number of grass species structurally adapted to making good turf is strictly limited, but there is no question that the best lawn grasses for temperate climates are found in the bent (*Agrostis*) and fescue (*Festuca*) genera. The species found in these two groups are dwarf growing and generally described as "bottom" grasses. Being low growing they are able to survive where competition from tall vigorous-growing species does not exist or has been removed. They are fine in leaf and markedly persistent even when not allowed to grow above the height of cut of the mowing machine. Altogether the bent grasses and fescues satisfy the conditions imposed to a marked degree, though the bent grasses are more aggressive and persistent than the fescues.

The bents, and to a lesser extent fescues, are capable of withstanding defoliation, and they show powers of aggression in spite of the mowing. They owe this to their propensity for forming tussocks, surface runners, and underground stems or rhizomes. The degree of aggressiveness is partly a reflection of species but is very largely decided by the strain of grass and its capacity for forming new shoots and leafage from buds at the base of the stems. Like other grasses the leaves are capable of growing up again from the base when clipped. Thus it is possible to make turf vegetatively from each of two plants of *Agrostis tenuis* that look outwardly identical, and to find the turf slow to form, less persistent and less vigorous in the one, whilst in the other a dense thick pile of permanent turf rapidly develops.

The species going to compose a good lawn are comparatively few as compared with the numbers found in a pasture or meadow. Indeed, good turf can be made of a single species or

a single strain. Although the species are few, the number of strains of finer grasses is very great, and the strain present may well be the determining factor of condition. The degree of improvement that can be effected in a lawn is often limited by the strain of grass present. The realization of the significance of strain in the grasses used for turf is important, and this aspect of turf management will no doubt gather significance in years to come.

There are only four species of bent, or *Agrostis*, of any real significance in turf culture, but each is represented by an almost endless chain of types or strains. Of these four species Browntop (*Agrostis tenuis* Sibth.) is the commonest, and it is safe to say that no lawn or turf area is entirely without it. The finest lawns are almost entirely composed of browntop, which spreads by short overground runners or by the development of underground rhizomes. Good strains provide a dense thick carpet of grass. Velvet Bent (*A. canina* L.) and Creeping Bent (*A. stolonifera* var. *compacta* Hartm.) are also found in lawns, but not to the same extent as browntop. These species spread by a series of overground runners, so that a small patch of either will tend to increase, provided the conditions are suitable. They are very variable in vegetative characteristics. The fourth species, Redtop (*A. stolonifera* var. *major* Malte, or var. *gigantea* Koch), is seldom found in good lawns but occurs at times in coarser and longer swards. It spreads by rhizomes but fails to tolerate keen mowing. The commercial seed of these species will be described later.

Among the fescues there are a number of species found in turf, some of which have commercial counterparts. Red Fescue is perhaps the commonest, some types being extensively creeping (*F. rubra* sub-sp. *genuina*), whilst others have only short creepers or no creepers at all. Fine-leaved Fescue (*F. tenuifolia* Sibth. or *capillata* Lam.) and Sheep's Fescue (*F. ovina vulgaris* Hack.) are tufted species of fescue found in turf, though they do not blend very well in closely-cut swards.

The variability in these species is very great indeed, some of them being more leafy whilst others are less leafy and more disposed to panicle production than leaf production. These species of bent and fescue are found growing naturally in poor soils; they are in fact poverty grasses, having fine leaves, which in the fescues are markedly xerophytic or drought resistant. Though

Fig. 1 (*above*).—Good and bad lawns. Experiments on the use of fertilizers. *Foreground*: Untreated plot invaded by moss.

Fig. 2 (*below*).—Neglected lawns. A neglected tennis lawn infested by earthworms and disease. The dark lines represent the effect of lime applied in the whitening.

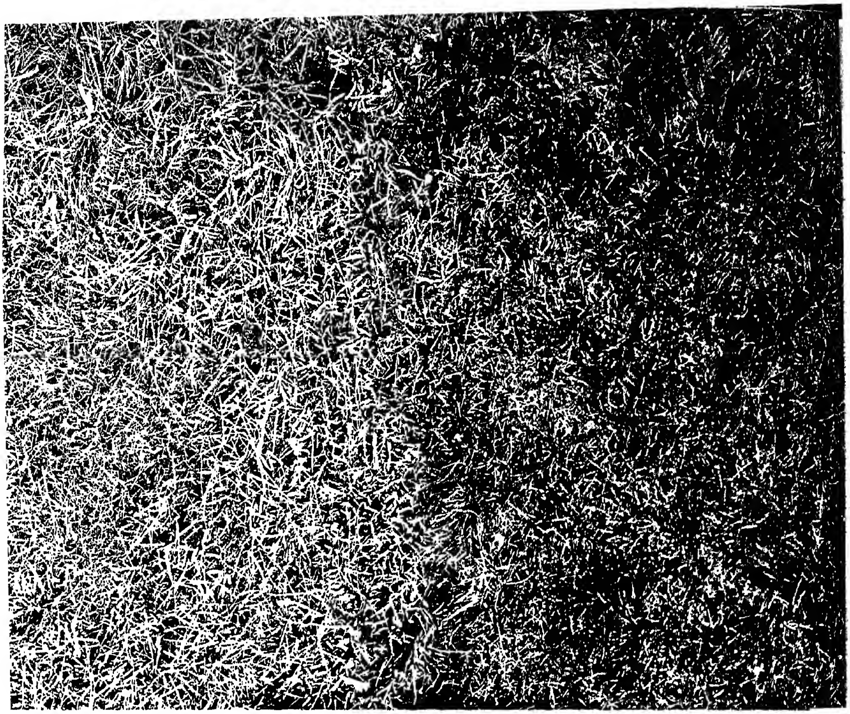


Fig. 3 (*above*).—Sowing seeds. *Left:* Sown with 90 per cent Chewing's fescue and 10 per cent perennial rye-grass. *Right:* Pure sowing of Chewing's fescue.

Fig. 4 (*below*).—Fescue turf invaded by annual meadow-grass.

bent is coarser-leaved than fescue it fines down under the influence of the mower, so that the leaves are often difficult to distinguish by the naked eye from those of fescues.

We are not concerned at the moment with the species or strains of fine grasses obtainable through seedsmen, but with the grasses found on turf areas that have never been sown down with commercial seeds but that are inhabited by species native to the district. Such indigenous strains are those that have adapted themselves to local conditions of soil and climate, and one advantage of making turf with sods is that, if local turf is used, strains of grass indigenous to the district are obtained.

Other grasses found in lawns may briefly be described. Thus, Annual Meadow-grass (*Poa annua* L.), or Annual Blue-grass as it is called in the U.S.A., is a common constituent of turf, being a vagabond or volunteer species. Its persistence is not due to any system of creeping stems or rhizomes but to its habit of forming large numbers of panicles below the level of the mowing-machine blade. Even though keenly mown, annual meadow-grass is capable of flowering and setting seed, and so maintaining or even increasing the number of plants in the sward. Other grasses do not adapt themselves to seeding in this way.

Other meadow-grasses found in small quantity in turf are: Rough-stalked Meadow-grass (*P. trivialis* L.), which is useless for fine turf because of its tendency to form on the surface runners that do not root down; Smooth-stalked Meadow-grass (*P. pratensis* L.), which is more valued in the United States than in this country, being there known as Kentucky Blue-grass; Wood Meadow-grass (*P. nemoralis* L.), which is not common and is confined to shady places; Bulbous Meadow-grass (*P. bulbosa* L.), which is occasionally found in turf in this country, but never on keenly-mown or intensively-managed turf. For instance, it may be found on fairways of certain seaside golf links in Kent.

On richer soils and on second-class lawns and sports grounds, Perennial Rye-grass is a common constituent, and there are many leafy forms that are markedly persistent in spite of mowing, but in competition with bent and under keen mowing perennial rye-grass is less aggressive and may gradually die out. Crested Dog's-tail (*Cynosurus cristatus* L.), though not a suitable grass in the finer swards, is often found on poorer soils on heaths and seaside places, where it forms a valuable

constituent of the natural herbage. In turf on soils that are markedly acid or approximating to moor land conditions, Wavy Hair-grass (*Aira flexuosa* L.) is found, and even the Early Hair-grass (*A. præcox* L.), which is capable of seeding, though mown, like annual meadow-grass. Under very acid conditions, even though the turf is being systematically cut, Moor Mat-grass (*Nardus stricta* L.) may be found. Care must be taken not to confuse these wiry-leaved grasses with any of the fescues.

Sometimes heath-grass (*Triodia decumbens*, Beauv.) contributes to swards on heathlands. Occasionally leafy strains of yellow or golden oat-grass (*Avena flavescens*, L.) are to be found in closely mown swards.

This chapter would not be complete without making some reference to a weed grass found in fine lawns and greens and known loosely as Yorkshire Fog. Sometimes the patches called Yorkshire Fog (*Holcus lanatus* L.) are in reality another species—Creeping Soft-grass (*H. mollis* L.) and both species are markedly persistent in spite of keen mowing. Whilst no doubt useful in coarser classes of turf these species are weeds as far as fine turf is concerned and therefore constitute a serious difficulty in mown herbage.

It will be seen from the above that the number of grass species found in natural turf swards is very limited. In a later chapter the commercial equivalents will receive attention.

SECTION II

NEW LAWNS

Chapter Five

The Construction and Drainage of Lawns

he construction of a new lawn is usually associated with the building of a house or with a scheme of general re-design of the garden, but on occasion the owner is fortunate enough to take over an area of undisturbed pasture, and, with little or no constructional work, achieves a tolerably good result. Such instances are rare and usually there is involved a constructional scheme depending in size upon the aspirations of the would-be lawn owner or upon the nature or condition of the terrain.

In making a new lawn the usual methods are either sowing, or turfing, though, as will be shown later, there is the third method—vegetative propagation. The general preparation of the site, its lay-out and cultivation, are virtually the same for each method, but it is necessary to come to a decision on the matter in the course of the preparatory work, as the final details vary to some extent.

Assuming that the site is a natural one and that little or no alteration in contours is necessary, it is still important to decide, for example, as to whether the turf on the site is worthy of attempts at improvement, or whether it must be removed. If the existing sward is to be retained it may be necessary to trench the site and put in a system of drains. Should the condition of the turf be such that removal is advisable, then the general lines of preparation for re-turfing or re-sowing must be followed in accordance with the description below. Assuming, on the other hand, that either general re-design is called for or a construction scheme is decided upon, then the first step is to plan the outlines of the lawn and any banks or undulations desired. This is where the ability to picture the finished effect is important, and assis-

tance may be given to the mind by means of stakes and lines. It may be the intention to use the lawn for clock golf, or as a miniature golf putting green, or as a combined croquet and putting lawn, or even to lay it out as a single rink for bowls. The future use of the lawn has a bearing upon the garden lay-out.

Grading the Site. Grading of the site for the future lawn is an important matter, and one in which many errors are commonly made. Every lawn has certain fixed levels, such as the paths, the house foundation, or perhaps the base of a tree or the bank of a stream. With these in view a correct yet pleasing and practical grading should readily be achieved. In arranging the contours, the question of surface drainage should be kept in mind, and also the fact that grading of any type is a costly process. Often the scheme involves obtaining a level surface from a slope or series of undulations, and in such instances a datum point or line should be selected and a peg driven in, leaving the peg 4 to 6 in. above the soil. From here should be set a series of pegs arranged in lines and cross lines at measured distances. Then by the aid of a straight edge and spirit level these stakes can be set level. To level up, soil is then applied to the surface in shallow layers and gradually levelled up with the tops of the pegs, using another straight edge. In other instances the question is one of providing a gradual slope or a series of gentle undulations to provide variety, or to cover obstacles like outcropping rock. Here stakes and lines will be found most satisfactory in guiding the moulding of the surface. By adjustments to the lines and stakes the work may be reviewed and modifications effected.

Where construction or re-construction involves only small changes in the grading, the changes can be made by the addition of extra top-soil, but if major alterations are in view it is important that they should be made with the sub-soil, the top-soil being removed, placed at one side and carefully saved until the grading is finished, when it can be returned. A similar depth of soil throughout is important because it will determine, to a large extent, uniformity of texture and colour in the subsequent sward. It should be realized that a medium loam soil will settle 20 per cent or one-fifth, and allowance should be made for this. Neglected grading is a frequent cause of failure to produce a good turf. Occasionally it is necessary to construct a lawn on a hillside, and here the draw and fill method is

adopted, an excavation being made, and the material thrown forward to produce the site, which may or may not be quite level. Here again the top-spit should be removed and the work carried out with a sub-grade. The common fault in this type of construction is to provide too shallow a depth of top-soil at the back—the deep part of the excavation—and an excess of soil on the filled portion; with care this can easily be avoided.

Pre-treating and Cultivating the Soil. Discussions frequently take place as to the best and most suitable depth of soil for the production of a lawn. It may be said that the more soil that can be provided the better, but unfortunately the question of cost frequently operates and usually the aim is to provide from 9 in. to 1 ft., though sometimes as little as 6 in. has given satisfactory results. Where the top-soil from a lawn has been removed for constructional work to take place, an excellent opportunity is provided for digging over the sub-soil and incorporating vegetable matter that will decompose and open up the soil. A dressing of coarse ($\frac{1}{4}$-in.) raw bones may be given also. Whilst it is true that the bulk of grass roots are concentrated in the top 6 in., nevertheless the longer ones will penetrate to a lower depth if encouraged to do so, and roots of the finer lawn grasses have been traced to 16 to 18 in.[4] If there is no question of removing the top-spit, the bulk of the cultivation should be given to that layer, but it is an advantage to double trench the soil, so giving an opportunity for improving the sub-layer.

For small lawns and lawns in restricted areas, hand cultivation is, of course, the only possibility, but on larger areas like sports grounds and playing fields, or on golf courses, large-scale operations become necessary and the cultivation is then carried out by plough and other agricultural implements. For areas that are intermediate between small private lawns and large areas, there are various small mechanical cultivators on the market to-day. One of these cultivates by a rotary action of the tines, whilst another consists of a small 5-h.p. tractor unit drawing a plough share or different forms of cultivator. On large reconstruction schemes such as are necessary where sports grounds are to be levelled or greens built up on a golf course, mechanical excavators are now used, and also steam tackle and tractor-driven ploughs to speed up the cultivation.

[4] *Jour. Bd. Green. Res.*, 1931, II, No. 5, 110.

In constructional work and preparation for turfing or sowing, thorough cultivation of the top-spit is essential, and it should be realized that any material alteration of this layer during the subsequent history of the turf will be very difficult, and therefore while the soil is bare every opportunity should be taken to improve it. Thus on very heavy soils the aim should be to incorporate gritty material such as coarse sand or fine coke breeze, and to work in well-rotted stable manure at the rate of 2 to 3 tons per 500 sq. yd. In doing so care should be taken that the organic matter* is well broken up, since if it is buried in large lumps, subsequent decomposition leads to settlement in irregular patches. This has sometimes been found the cause of trouble on artificially-made golf greens. Other organic materials that may be used for the amelioration of heavy soil are granulated peat, spent mushroom manure and hop manure. With sandy soils it is advisable to work in well decomposed manure at the rate of from 3 to 4 tons per 500 square yards, and well rotted cow and pig manure are useful on this type of soil. Further, if a supply of more loamy material or leaf mould can be obtained it may be added and worked into the top spit. The amount of amelioration that is possible is, of course, dependent upon the funds available, the size of the scheme, and the availability of organic matter in these days of mechanical transport. The addition of organic matter on sandy soils improves the water-holding capacity and encourages a deeper root system, while on heavy soils the introduction of grit and organic matter improves the soil particles and the porosity of the soil.

Before a newly-constructed lawn or a sports ground can be sown or sodded, consolidation must be carried out. On small areas like lawns or putting greens this is best done by means of the feet; thorough trampling is the most efficient way of finding the hollows. On larger areas the usual methods adopted are rolling followed by cultivation and further rolling.

Fallowing. The next question to consider in connexion with a new lawn is that of fallowing, which involves the destruction of

* The term "organic matter" and not "humus" has been adhered to throughout. "Humus" is a constituent of the colloidal complex of the soil particle which acts as a reservoir of bases like lime, potash, and magnesia. The "humus" content influences the fertility, water-holding capacity, and physical condition of the soil, and the supply is increased by the incorporation of organic matter like dung.

the weeds that develop from the dormant weed seeds present in the soil. This operation is most important where the land is going to be sown, but is less so when sodding is to be done. Whilst it is true that the usual weeds that germinate along with the seeds are annuals, they nevertheless may cause a great deal of difficulty. In the seedling stage the finer grasses do not compete favourably with weeds. The following are the species of annual weeds that may cause most difficulty: groundsel, mayweed, various speedwells, common chickweed, annual meadow-grass. Very often imported soil is a source of weed invasion, because many soils purchased for the purpose of making up levels have been removed from arable fields or from building sites that may have lain idle for some time and thus become heavily charged with weed seeds. The importance of fallowing the soil cannot be too strongly stressed, because it is an aspect of lawn production that is almost invariably neglected. Numerous instances are known where a crop of weeds has appeared amongst the finest grasses, and the seedsman has been wrongly blamed for the condition. Actually many of the weeds that appear in newly-sown turf are of a type that never appear in properly-cleaned purchased grass seeds. A clean turf cannot be made on a weedy seed bed.

Summer-time is the best period of the year in which to carry out fallowing, which is done by alternate hoeings and rakings to destroy the weed seeds as they germinate and encourage another crop to sprout for similar treatment. The rhizomes or underground stems of creeping soft-grass, couch, convolvulus and thistle, are occasionally found in soil to be used for lawns, and whilst three of the species do not cause much difficulty it is important to remove all the rhizomes or portions of creeping soft-grass, because this is a species that will establish itself from portions of rhizomes among sown grasses, and will remain persistent in spite of regular mowing.

Although it is not often practised in this country, green manuring of an area to be sown for a lawn is a practical proposition. It may best be carried out by sowing white mustard at the rate of 14 to 20 lb. per acre. The crop helps to choke weed plants and when 6 to 8 in. high is rolled and dug into the top-soil, this increasing the organic matter and conserving soil nitrogen. Another method that is worthy of adoption is to grow a crop of early potatoes on the site, getting these off by

early or mid-August in time to enable autumn sowing to be carried out.

Final Preparation of the Soil Bed. Finally, the preparation involves the production of a soil bed that should have a fine tilth, and if grass seeds are to be sown no particle of soil should be greater than a grain of wheat. Alternate cross-raking and cross-rolling should be carried out, choosing weather conditions that will enable the soil particles to be crushed and worked down. The rake should also ensure the removal of rubbish like roots, surface stones, and twigs, and should be so manipulated that the surface is not left in humps and hollows that will cause subsequent difficulty. Whilst very fine tilth is necessary for sowing the seeds of the finer grasses, it is not so essential that the surface should be so fine for turfing, nor is it necessary to be quite so particular in the fallowing operations, although it is stressed that the removal of the rhizomes of creeping soft-grass is very important. Both for sowing and sodding, however, the soil bed must be firm so that no settlement is likely to take place subsequently.

Drainage Systems. Some reference must now be made to the drainage of the newly-constructed lawn. Whether the site is to be sown or sodded attention must be paid to this matter, except where the soil is very light and porous, or in a very dry district, or on land with a good natural slope. Draining of a lawn in course of construction is best carried out in the sub-soil before the return of the top-spit, but where the top-spit has not been removed it is, of course, necessary to cut through both. Good turf cannot be grown in a water-logged soil, and the indications of the need for draining are soft spongy areas, prolonged ponding on the surface after rain, and on existing swards the presence of weeds such as selfheal, moss, sedges like carnation-grass, or dwarf rushes like toad-rush. Proper drainage ensures good aeration, a better distribution of plant foods, an improvement in soil texture, and a circulation of sufficient moisture, so that the plant roots are encouraged to grow deeper; when well drained the soil is also warmer.

A badly-drained lawn or sports ground is less useful in winter or wet weather, and the improvement of drainage on playing fields is a matter of importance if the maximum number of

days of use are to be obtained and a wet puddled surface avoided. In conditions of inadequate draining a bad physical texture of the soil develops through the churning up of the surface and the sealing of the surface layer. Under wet conditions growth is slower in starting in spring and finishes earlier in the autumn. Further, on a badly-drained soil snow lies longer, and this is a point of some importance on turf used for winter games like golf or football. In summer the turf on badly-drained clay soils bakes and cracks, the surface having been "poached" by the feet of players, just as the farmer finds will happen with the feet of his sheep. The water table rises with heavy rainfall and falls in periods of drought; in wet conditions it may come to the surface, and the purpose of draining is to lower this water plane.

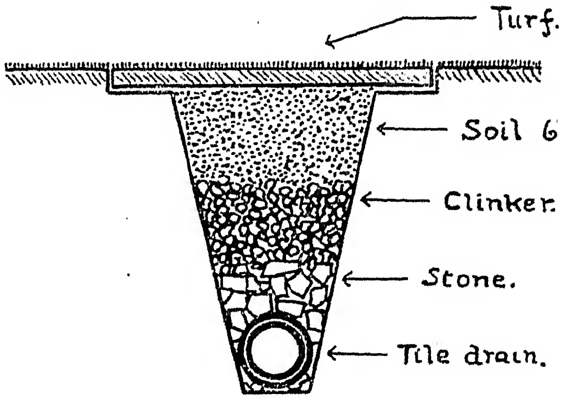
In a drainage scheme there are four fundamental factors that need consideration: (1) the depth of the drains; (2) their distance apart; (3) the fall, and (4) the outlets.

The depth at which the drains are placed is determined largely by the nature of the soil; the heavier the latter is the nearer the drains should be to the surface. Much heavy land is drained too deeply, and as a rule it may be said of lawns and sports turf, where quick draining is essential, that the drains should be shallower than is customary in agricultural practice. On medium soils the drains may be deeper and less frequent. Thus on heavy soils for draining lawns and sports grounds 1 ft. 6 in. to 2 ft. is usual down to 2 ft. or 2 ft. 6 in, at the low end. On medium loam the drains may be 2 ft. to 3 ft. deep, whilst on sandy loams a depth of 3 ft. to 4 ft. is permissible. The distance apart of the drains is also determined by the nature of the land; on very heavy land they may be placed as near as 10 ft. apart or up to 20 ft. apart. On medium land they should be about 25 ft. apart, and on open soils 30 ft. to 50 ft. apart. On many sports grounds and even golf fairways that have been made from old pastures, the land may have been ridged up and here the frequency of the hollows determines the frequency and the position of the drains. The fall of the drains should be as much as the conditions allow, and for quick draining of say a tennis lawn, a fall of 1 in 100 is usual, but 1 in 300 or even 1 in 600 may be adopted on larger areas; with the gentler gradients, however, great care is necessary to ensure an even and gradual fall. The outlets of the drains are most

important; they should be free and should allow the water to fall clear, and should also be covered to prevent their invasion by vermin.

There are several methods of under draining, two old ones being bush draining and stone draining, which are adopted in wooded and "stone" country respectively, but nowadays it is mostly done by tile draining or by mole draining. These two methods, together with surface and vertical draining are considered here.

Tile Draining. The cylindrical tile drain first appeared in 1843, since when it has been extensively used on hundreds of thousands of acres of land. In small lawns it is usually only



Text Fig. A.—Section of tile drain.

necessary to have one main drain running along the diagonal of the area in the direction of the fall, or it may be run straight through the length of the lawn in the direction of the fall. To this are run side drains giving what is called the herring-bone system. On larger areas parallel main drains are put in with 4-, 6-, or 8-in. pipes, and laterals about 12 ft. long made from $2\frac{1}{2}$-in. or 3-in. tiles. The angle of entry of the lateral should be about 40 degrees, and the slope should be 1 in 50 or 1 in 75. Only pipes free from fractures should be used, and the main should be laid one lateral pipe width lower than the outlet of the lateral so that the water in the latter discharges on to the top of the main. The whole scheme should be well planned and thought out, and excavation should begin at the outlet, working back towards the ends. On land already carrying turf it is usual to remove a sod 14 to 16 in. wide and to cut a trench 12 in.

wide so leaving a narrow ledge along each side. The drain should be slightly tapered to the bottom and the top-soil thrown at one side and the sub-soil on the other. When the drain is complete the flow may be tested by pouring water down, and the pipes should then be laid from the extremities of the system forward towards the outlet, being placed close together and covered with stones, then broken stone, clinker, and fine ash placed over the top. In sports grounds and lawn work it is best to remove most of the sub-soil and to fill up within say 6 in. of the surface with stone and ash and then to replace the top-spit. It is essential that the outfall should enter the ditch with a clear outfall and it should be wired over. Most of the excavation work in tile draining lawns and sports grounds must be done by hand, though there are mechanical trenching tools for doing the major part of the trench, and these are used on large areas undergoing draining by contract. In large schemes, especially when the slope is uncertain, the assistance of a surveyor may be necessary.

The cost of tile drainage varies considerably with the nature of the soil, depth of trench and frequency of the drains. An approximate price for a 2 ft. to 2 ft. 6 in. trench would be about 44*s*. per 10 chains (i.e. 220 yards), and the present price of 660 pipes, 3 in. diameter and 1 ft. long, would be in the region of 88*s*.

Mole Draining. Tile draining of large areas of turf is often precluded owing to considerations of cost, and in many instances the adoption of a system of mole draining [5] is possible. Although it may be carried out on open soil it is usually done on turf that has been established. Mole draining is carried out by drawing through the soil a steel cartridge-shaped rod fixed to the end of a knife-shaped coulter, the apparatus being called a mole-plough and costing from £7 to £12. The rod compresses the soil, so leaving a tubular channel at the required depth. Whilst not so durable as tile drains these channels may last up to 10 or 12 years, although 5 years is probably nearer the usual period. Deep mole drains, however, have been known to exist for periods of 20 to 30 years. The method is restricted to land having a clay sub-soil and free from stones or pockets of light soil. The land must also have a natural regular slope with a minimum fall of 1 in 150. The fall must be even, and hence or

[5] A fuller account appears in *Jour. Bd. Green. Res.*, 1932, II, No. 7, 249.

ridge and furrow land the drains must be run parallel with the furrows or they will not be even in depth.

Mole draining of turf is best carried out in the late autumn and winter months when the soil is sufficiently moist to permit the mole plough to move relatively easily. Several types of mole plough are available, and one that is commonly used in draining sports turf is provided with a disc knife fitted in a frame; this cuts the turf and thus minimizes the temporary damage. The plough may be drawn either by direct haulage, when it is necessary carefully to choose weather when the surface is dry enough to take the tractor without much damage, or by cable haulage, which has considerable advantages over direct haulage when dealing with turf. When mole draining is contemplated a very careful survey of the land is necessary, especially in regard to slope and contours.

The object of the mole draining is to remove the surface water quickly, and drains at depths between 12 and 18 in. are usual. The drains should, of course, be adequate in size and number to cope with the volume of water reaching the land, and shallow drains of a small diameter close together are more effective than those that are deeper, larger, and less frequent. It is often possible to arrange for a mole drain to lie 3 to 4 in. deep in the sub-soil and a total depth of about 18 in. is usual. The distances apart will vary with the type of soil and the nature of the land, but from 3 to 10 yards is the usual distance, although instances are known where on ridge and furrow land 2 or 3 drains have been put in in the furrows with only a few feet between them. Drains of 2½ in., 3 in. or 3½ in. bore are most common and it is usual to regard 220 yd. (10 chains) as the maximum length of a drain with 3½ in. bore.[6]

The question of outlets in a system of mole draining is of great importance, and deserves more care than is usually given; proper unimpeded emptying of the drains determines their efficiency and permanency. The best results are obtained by running the moles into an open ditch or into the bank of a stream, and the outlets should be protected from caving in by inserting a few lengths of tile or a length of iron pipe. The plough is inserted at the low end of the slope and is drawn uphill and returned to the bottom for the next pull. It is very often possible to insert the plough into the bank of a stream, but if

[6] Leaflet No. 12, Ministry of Agriculture.

not it may be started 3 or 4 yd. from the edge and piped to the ditch or stream subsequently. In any event the outlet should be tiled and netted. Where it is not possible to run the moles into an open ditch they may be joined to pipe drains by means of eyes that are specially constructed junctions.

As regards the cost of mole draining, the size of drains, the depth and distance apart, all have a relationship to this problem, and whilst undoubtedly the cheapest form of mole draining is by steam tackle (using two engines and dragging the plough up and down the slope), this method is difficult on sports grounds on account of the damage likely to be caused in manœuvring the plant. In fairly large contracts where several thousand yards of draining are to be done, the cost appears to be in the neighbourhood of 1*s.* 4*d.* to 1*s.* 6*d.* per chain, using cable haulage and a 3-in. plough, but where direct haulage can be adopted the cost is lower, at about 10*d.* to 1*s.* per chain. The costs as well as the results of several schemes of mole draining on sports turf have been examined, and it would appear that with drains at 6 ft. to 9 ft. centres the cost is in the neighbourhood of £4 per acre. The method, whilst very satisfactory on the right soil and sufficient slope, is of course unsuitable for small areas like private lawns where a system of tiles is of necessity usually adopted.

Other Ways of Draining. Open or surface drainage has a very limited use on sports grounds, but a combination of open drains and tile drains is frequent. Open drains are useful on golf courses and sports grounds for trapping surface water on slopes, for example before it reaches the playing area, but their use is restricted owing to their interference with upkeep operations and the game. They are often useful when a large volume of water is to be removed, or where the water-table is very near the surface, or where the fall is so slight that it is impossible to sink a pipe. Open drains also prove useful for receiving the discharge of tile or mole drains, but they are more expensive to maintain than covered drains and are subject to erosion and chokage by vegetation.

With lawns that have been excavated from a slope on the draw and fill principle an area at the back is apt to become water-logged through moisture seeping out of the bank and running over the surface. In such an event, if it is impossible to put in an open drain, a tile drain should be inserted in which

ash has been filled almost to the top. Such a drain may be inserted by placing it in a hollow as a further trap for the water.

Vertical drainage is practicable in conditions where a layer of clay overlies a porous stratum of sand or gravel. Small wells are dug through the clay, to contain a column of drain tiles surrounded by gravel. The end of the column is covered with a slate or flat tile and then with surface soil.

When constructing a lawn or green on moist heavy soils, it is also customary to cover the sub-soil with a layer of coarse ashes which then comes into direct contact with the ashes placed in the drains built in the sub-soil. On heavy soils this method has proved very successful provided a good layer of well-prepared top-spit is replaced to form the surface. In any system of drainage a plan showing all drains and outlets should be made as the work proceeds.

Drainage Difficulties. In concluding this chapter some brief reference must be made to the troubles attending a system of drains. The most serious is the displacement of tiles, which steadily leads to blockage and the welling up of water on to the surface. The only way in which this can be cured is to lift the affected part and relieve the blockage. Another cause of trouble is the growth of roots of trees like willow and birch into the pipes. The slowing down of the current of water then leads to silting up and blockage. The adoption of collared pipes adjacent to trees is therefore to be recommended. Often, pipes will become choked with sediment through the fall not having been uniform, a dip in the fall causing suspended matter to settle and cause sealing up. Very often, too, silting up of the pipes is due to a bad outfall of the system. In the event of repairs being required location of the lines is greatly facilitated if a proper drainage record and plan have been kept, especially on large schemes where drift maps should first be consulted.

In many instances surface wetness of the turf is not due so much to bad drainage as to a sticky gluey surface caused by puddling. Here, pricking and the application of gritty material like sand, charcoal or coke breeze will greatly relieve the condition.

The question of drainage has been dealt with at some length because it is often neglected when new lawns or grounds are constructed, and it is just as important for small lawns to be well drained as for large areas like golf courses and playing fields.

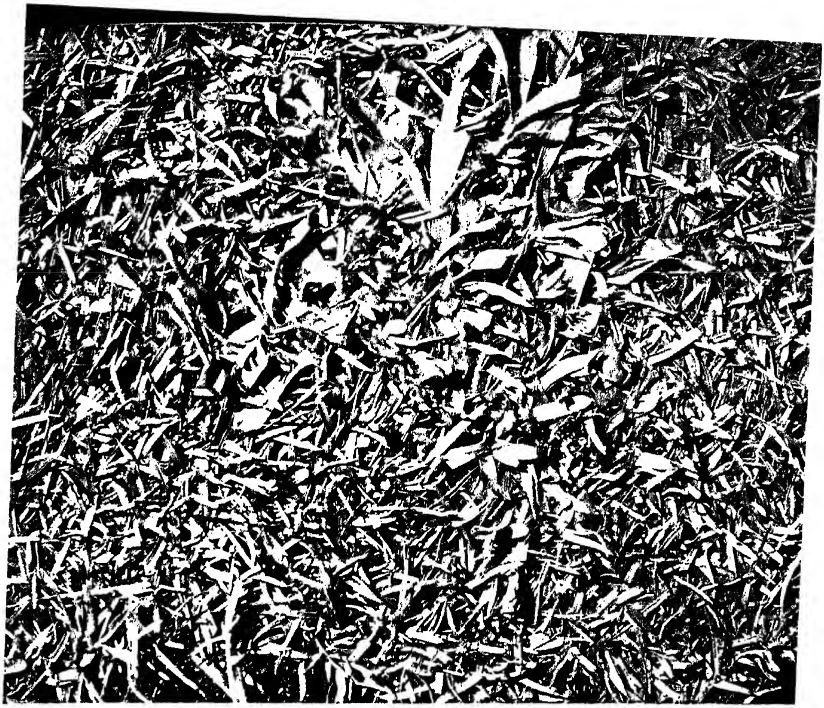


Fig. 5 (*above*).—Bent turf containing patch of Yorkshire fog.

Fig. 6 (*below*).—Sowing grass seeds.

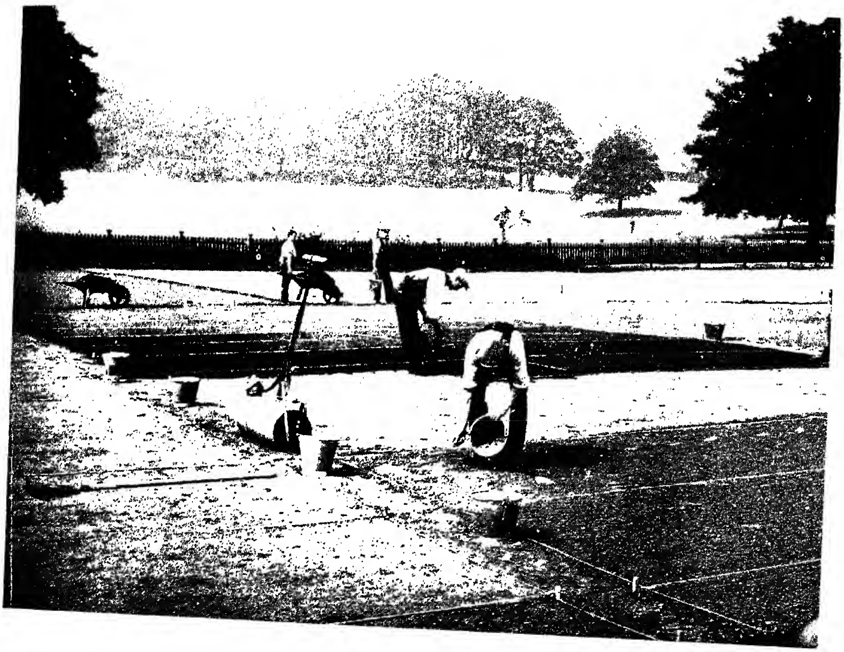


Fig. 7.—A plant of *Agrostis canina* showing extensive stolon formation.

Fig. 8.—A plant of Bermuda Grass (*Cynodon dactylon*) as used in tropical countries

Chapter Six

How to Choose and Lay Sods

he advantages of lawn making by sowing seed are so frequently stressed in seedsmen's catalogues that the amateur often forgets that lawn production by sodding has in some respects decided advantages over seeding. Perhaps the chief of them is in point of time, because an area of land can be more rapidly clothed in turf, even though it may be overtaken in the long run by a seeded sward. Sodding has the added advantage that it may be carried out in the "off season", at a time of year when labour in the garden may be more easily allocated to the work, whilst on the other hand sowing must be done in late summer or spring at times when labour is fully occupied in other directions. Sodding is, however, more expensive in original cost than seeding, for not only does the turf cost more on a yardage basis, but there is the additional cost of carriage, which may be considerable if the turf has to be brought any distance. In many ways it is easier for the amateur to make his lawn from sods rather than seeds because the soil needs less careful preparation and sodding is less tricky than seeding. It is also true to say that some very bad results are achieved with sods by using those containing undesirable grasses. On large constructional schemes sodding is precluded because of cost, and here seeding must needs be carried out.

The main difficulty in making turf from sods is to locate a source of really good turf—and good turf is exceedingly rare. For one thing it is seldom entirely free from weeds, but in choosing turf it is actually more important to pay attention to the species of grass present than to the weeds. The identification of grass species in a turf sward is not easy, so if the amateur is choosing turf it is desirable either to take advice on the suit-

ability of the species present, or only to deal with a supplier whose stock of turf has already been approved as regards species and suitability. For general purposes old parkland turf is suitable because it lifts readily, is strong enough to withstand transport, and usually contains only finer grasses, mainly species of bent and fescue, which will work up to a turf. Such turf is also reasonably free from weeds, and such species as are present will either die out as a result of cultivation, or may be removed by special operations. Good parkland turf obtainable in the London area costs, at lifting site, about 16*s.* per 100 turves, 3 ft. by 1 ft., about 30 yards going to the ton.

Marsh turf such as is obtainable from the salt marshes of Lancashire (Morecambe Bay) and Cumberland (Solway estuary near Silloth) as well as other districts, has a high reputation for laying bowling greens. The Cumberland, or Silloth turf, has earned a high reputation, but to-day supplies of good turf are becoming more limited. The species present in sea marsh turf are strains of *Agrostis stolonifera* var. *compacta*, Hartm., and strains or even varieties of *Festuca rubra genuina*. Some inferior classes of this turf contain sea poa (*Glyceria maritima*, Wahlb.), which does not make a turf. The main variety of red fescue found on sea marshes is *F. rubra* var. *glaucescens*. Analyses show that the relative proportions of the red fescue and bent vary from place to place, so that definite analytical figures cannot be given. This turf is lifted in 1-ft.-sq. sods for ease of transporting. It is a heavy material and a square yard of the turf, cut 1¼ in. thick, will weigh about 112 lb. so that the cost of transport for an area like a bowling green is considerable. The F.O.R. price of sea marsh turf is from 1*s.* 2*d.* to 1*s.* 6*d.* per square yard and carriage per ton (18 to 20 sq. yd.) is approximately 25*s.* to the London area, i.e. 2*s.* 4*d.* to 2*s.* 9*d.* per square yard for turf delivered to site.

Downland turf overlying chalk, mainly in the south and east of England, provides a useful source of turf. The soils underlying this type of turf are thin, and a herbage of sheep's fescue, bent grass, and crested dog's-tail, with some yellow oat-grass, is typical. Unless the turf is of the old matted fibrous type leguminous plants may be numerous, as well as miscellaneous weeds, among which burnet is common.

On stiff soils derived from Boulder Clay or other clay formations, much of the land has been worked out and allowed to

"tumble-down" to grass. Semi-natural vegetation has developed, and where acid conditions prevail, bent grasses, fescues, dog's-tail and Yorkshire fog occur. The weed flora is more extensive, but good turf may be evolved from this type of sward.

Turf suitable for lifting as sods for lawn work may also be found in extensive areas on the millstone grit or other non-calcareous grits and sandstones. Such turf is characteristic of many parts of the north of England where rainfall is high and smoke pollution aids the depletion of bases from the soil. The semi-natural vegetation found on these types of soil contains grasses suitable for turf production, and good results are obtained by reducing the acidity, applying phosphate, and by reducing the amount of acid mat by boxing the turf. Creeping soft-grass is a frequent constituent of this type of sward so that in choosing sods care should be taken to avoid the patches of it.

Good turf is also found on heaths where the soil is poor and semi-natural associations of plants have gradually become established. On poor uplands in many parts of the country occur large tracts of grass in which the finer-leaved grasses, the bents and fescues, predominate. Unfortunately such areas are usually badly placed or inaccessible from the point of view of disposing of the turf, but such material would provide unlimited supplies of sods. Much heath and moorland turf contains moor mat-grass (*Nardus*) or heath-grass (*Triodia decumbens*, Beauv.), but if a good heath or moorland turf containing dominantly bent grass and some fescue can be obtained it works down very satisfactorily for a turf sward. This class of turf is usually very matted, and is therefore not so suitable for lawn tennis or cricket wickets, but makes excellent turf for golf or ornamental swards. Practical experience and experiments suggest that the grasses in heath and moorland associations are to be preferred to those in sea marsh turf, especially as sods of the latter contain a layer of heavy clay silt. Heath and moorland turf is usually very free from weeds, the principal species found being cat's-ear, which is easily removed, heath bedstraw, which dies out under mechanical operations and manuring, and wood-rush, which also gradually disappears with the mowing.

It will be apparent from the above that the best types of turf for obtaining sods are found as semi-natural vegetation on the poor soils, and, indeed, the finer-leaved grasses useful for turf

are "poverty" grasses, a fact that is often forgotten in their subsequent maintenance.

In all instances in which turf from an outside source is purchased, it is worth inquiring whether any preliminary cultivation has been given to it in its natural situation. On golf courses preliminary cultivation can readily be carried out before lifting the turf, but purchased turf has commonly received no such treatment and the subsequent laying and management are thus made considerably more difficult.

The first stage of lifting is to cut the turf into parallel strips, guided by a line and using a turf race or "half-moon" turf cutter; cross cuts are then made to give pieces of the required size, and the sods are lifted by means of a turfing iron. As very few people can lift turf to uniform thickness it is better in practice to lift the sods say 2 to 3 in. thick and to box them down in a turf gauge-box. These boxes consist of a shallow tray with three sides, the sides being of the same height as it is required to make the finished sod. The turf is placed, grass down, in the gauge-box and the loose fibre and soil on the underside are removed by planing them off with a scythe blade or a two-handled knife. The actual thickness and size of sod must be decided by the strength of the fibre; if the turf is weak, sods of 1 ft. by 1 ft. should be cut, but turves 1 ft. by 3 ft. and 1 ft. by 2 ft. are often used. Parkland and moorland turf when bought is usually delivered in 1 ft. by 3 ft. sods rolled for convenience of transport.

As regards the most suitable thickness, most practical men agree that the best results are obtained by cutting the turf as thinly as possible, but the usual thickness is from 1 to 1½ in., though excellent results have been seen where the turf was cut as thinly as ½ in. Experiments that are still in progress indicate that the practical man's views on the thickness of sods are substantiated by scientific fact. Preliminary tests recently carried out show that the general trend is for thin sods to grow a better root system than thick ones; thus sods ¾ in. thick had a better root development than sods cut 3 in. thick. The experiments were carried out with very matted parkland turf.

Before laying the sods on the prepared site it is advisable to pass each sod across a bench for inspection when any rosette weeds present can be pulled out or pushed through from the back. Similarly each should be scrutinized for plants of York-

shire fog, or creeping soft-grass, and turves heavily contaminated with these grasses should be rejected or placed on one side for turfing unimportant parts of the work. Turves containing small pieces should be rigorously hand picked. In constructional work, especially on big schemes, the use of a turf-plough is convenient for lifting large areas of flat turf rapidly—though less accurately than by hand—in long strips, which can then be cut into convenient lengths and rolled. The plough is unsuitable on ridge and furrow land or where the land is at all uneven. Also, in the construction of banks and mounds turf may be cut up into long bands, rolled back spirally for several yards and left standing in situ; after the constructional work is finished the turf is then rolled out again.

Some practical greenkeepers cut the edges of their turves at an angle instead of vertical—there are special turf races for doing this—and whilst this method gives excellent results in capable hands, it is apt to result in drying out and curling up of the edges where the work has not been carried out so skilfully or where drought has intervened.

Having obtained a supply of turf that has been cut accurately into pieces of equal area and boxed to uniform thickness, laying can commence. If the sods are delivered and it is not possible to commence work at once, they should be laid out flat and any rolled turf should be opened out. If turves are left standing rolled or stacked, they soon discolour and the lawn suffers a preliminary set-back. Even if frost intervenes and delays the work of laying, the sods will not be adversely affected when laid out. Before laying the turf it is a good plan to dress the prepared bed with fine raw bone meal at 2 oz. per sq. yd., especially on poor land. On situations removed from a source of water for worming, the soil may be dressed with lead arsenate at 2 to 3 oz. per square yard, lightly raked in, since it has been shown experimentally [7] that this material when placed under the turf gives a high degree of earthworm control. The material also controls other soil pests. For small lawns or areas near a supply of water this additional initial expense is, however, hardly warranted.

Before laying the turf it is important to see that the formation level has been accurately finished and that the area has been pegged out at 10 ft. centres. Turfing should commence at one

[7] *Jour. Bd. Green. Res.*, 1935, III, No. 12, 58.

side or corner and work across the area. Laying should be carried out in a forward direction, i.e. the man laying the turf should face the unturfed soil and he should stand upon a board so that foot indentations are not made in the newly-laid turf. The sods should be laid with the joints alternating, as on a flagged pavement or as the bricks in a wall, and they should be packed closely together. Beating of the turf is usually recommended, but is seldom necessary if the soil bed has been well prepared and the sods are cut to uniform thickness. If there is a lump in the turf then it should be regulated from below by the removal of soil. Beating down of the turf on such lumps rarely succeeds and often leads to unequal compression of the soil. In the laying of a flat bowling green it is usual to commence at the corner of the green and work at an angle of 45 degrees to the line of play, and 12-in.-square sods are necessary to ensure accuracy in laying.

Once the laying is completed, top dressing with sand, or soil containing a high proportion of sand, should be carried out, and the material worked into the joints between the turves because this facilitates knitting in the lateral direction. After this material has been well worked in, rolling can be carried out once over with a roller weighing about 2 cwt. An application of fine compost may then be given. If frost lifts the turf or the latter is of a spongy nature, repetition of the rolling may be necessary. At this stage the turf should be left until growing weather commences, when a spring application of fertilizer may be considered necessary. On the other hand, if the soil has been well prepared and pre-treated with bone meal it is probable that it will not require much treatment other than mowing for the first part of the season. Composting of newly-laid turf is valuable because it helps to find the small depressions in the turf, and may be done at intervals during the establishment period. It also acts as a mild fertilizer and mulch.

Sodding of lawns and greens is usually a winter operation, but it may be carried out at almost any time of the year provided there is an adequate supply of water for application in dry periods. In practice, however, most re-turfing is done between September and early February, although good results have sometimes been seen from turf laid as late as April. Late work invites damage in dry weather. On light sandy soils the earlier the re-turfing is completed in the winter the better—in

fact, the aim should be to finish before the old year is out. On other soils it is usual to try and complete the work by the end of the first month of the new year.

During summer weather newly-laid turf, especially on clay soils, is inclined to crack, and should this happen, watering will be necessary and top-dressing for the purpose of filling in the cracks; mulching the sods is also desirable. During the spring it is wise to carry out a further inspection for weeds and to remove any rosette weeds that may be present, leaving the creeping weeds for mechanical operations as soon as the turf is well enough knit. This is particularly important with sea washed or sea marsh turf, which may contain plants of sea plantain, tarweed, sea milkwort and thrift.

Chapter Seven

Grasses Procurable in Commerce

The number of varieties of grass seed suitable for the formation of the finest lawns, obtainable in commercial quantities, is strictly limited, but if the range is widened to include varieties employed in the production of turf for other purposes also, their number is proportionately increased. It must be realized that many of the species obtainable through the seedsman, while often botanically the same as those found in natural turf, may differ considerably in turf-forming capacity, and that many of the strains of grasses grown for seed generation after generation are more adapted to production of seed-stalk than leaf—and it is leafage that is required for turf formation. There is, therefore, room for the production of seed crops from selected strains of grasses, such as those found in the finest indigenous turf, and capable of producing leafy, persistent swards. It may be well to describe the various species and strains obtainable in commerce with their turf-forming propensities, giving details of the usual purity and germination of the seed, as a preliminary to discussing seeds mixtures and the purchase of seeds.

The Fescues. Among the fescues used in turf production there are two main groups, the red fescues and the sheep's fescues, which are distinguishable by the nature of the leaf sheath* on the non-flowering stalks. In the sheep's fescue this sheath is split, whilst in the red fescue the sheath is entire. The dwarfest of the sheep's fescues is Fine-leaved Fescue (*F. ovina* L. var. *tenuifolia* Sibth. = *F. capillata* Lam.), which forms dense compact tufts

* The leaves of grasses are attached to the stem at the nodes and each consists of two parts—a lower portion surrounding the shoot and called the "sheath" and an upper portion called the "blade".

and is adapted to peaty and dry soils. The wiry or bristly leaf is permanently folded and the plant forms only intra-vaginal shoots.* It is a perennial and under natural conditions flowers in June and July, producing a seed 2 to 4 mm. long with no awn.† The standard of purity and germination is lower than in other fescues, the purity being usually between 80 and 90 per cent and the germination at least 70 to 80 per cent in 21 days. Harmful weed seed impurities liable to be present include sheep's sorrel and Yorkshire fog. The retail price of this seed fluctuates and whilst some years ago it was approximately 1*s.* 2*d.* per lb. it rose to four times this, then fell back to 3*s.* per lb. and the seed is still scarce. As a turf-forming species it has points in its favour, but it does not blend so well as other species of fescue and is rarely used alone. Turf sown from this species alone is dense, dark green in colour with a "dappled" surface and a tendency to form a grain (see Fig. 33).

Another fescue belonging to the same group is Sheep's Fescue (*F. ovina vulgaris* Hack.), but commercial seed true to name is very scarce and tests with seed purporting to be sheep's fescue have shown that in many cases hard fescue or fine-leaved sheep's fescue was being sold. The seed is 3 to 4 mm. long, has a short awn point and the plant is tufted and of similar habit to fine-leaved sheep's fescue. Perhaps the commonest of the sheep's fescue group is "Hard" fescue, which is the commercial term for varieties grouped together as *Festuca duriuscula*, a botanical term that has also been applied to some of the red fescue group. It appears, however, to consist of a number of varieties and even sub-species and in fact much of the hard fescue of commerce can be classified as *F. longifolia* Thuill. Seed supplies are variable in quality but in good samples the purity should reach 90 to 95 per cent and the germination 80 to 90 per cent in 21 days. Until recent years a common price was 8*d.* per lb. but to-day it is from 1*s.* 3*d.* to 1*s.* 6*d.*, i.e. of similar price to Chewing's fescue. Commercially the term "Hard" fescue is almost interchangeable with sheep's fescue and this species, like those mentioned

* Every new stem arises within the angle (axil) of the old stem and the leaf sheath. If the stems grow up within the sheaths this is the intra-vaginal mode producing tufts of foliage. If the shoots pierce through the sheath close to where they arise and grow out horizontally this gives the extra-vaginal mode and a loose open habit results.

† A bristle-like appendage generally associated with grass seeds. It may be terminal, basal or affixed midway to the glume.

above, is obtained almost entirely from Central Europe where the suppliers class them as natural grasses.

The name Creeping Red Fescue (*F. rubra* sub-sp. *genuina* vars.) covers a number of varieties of red fescue able to grow in all kinds of situations and which are markedly drought and cold resistant. The plant produced is wiry leaved and spreads by underground runners, since it produces extra-vaginal creeping stems as well as some intra-vaginal shoots. The seed is 4 to 5 mm. long with an awn and is employed to some extent in agricultural practice though mostly in lawn mixtures. There is a difficulty in obtaining stocks free from the seed of rye-grass, which if present, is detrimental to the subsequent sward.

One strain of creeping red fescue of German origin is known as "Steinach". The seed has a purity of 93 to 95 per cent and a germination of 92 to 94 per cent, and the price is about 3*s*. 9*d*. per lb., but the cost is variable, having in recent years been as much as 4*s*. and 4*s*. 6*d*. per lb., though before that it had been obtainable at about 1*s*. 9*d*. per lb. Selection work with red fescue has been carried out in this country at the Welsh Plant Breeding Station, with the result that a type known as S.59 has been produced in commercial quantities, and turf of it has been grown at St. Ives in comparison with other fescues. It provides a sward of good colour, resistant to drought and cold, and is markedly uniform, being finer in leaf than the creeping red fescue of German origin. All the strains tested are somewhat susceptible to Corticium disease (q.v.). Another form of creeping red fescue is sometimes referred to as variety *arenaria*, but how much of this conforms to the botanical species of *Festuca genuina* var. *arenaria* is difficult to say. In recent years a certain amount of red fescue has been harvested by hand from the sea marshes of the Solway and on the borders of Morecambe Bay. This is the botanical species *F. rubra genuina* var. *glaucescens* Hack., and the seed harvested has been used in lawn mixtures with success. The plant is slightly glaucous in colour and forms a turf finer in leaf than the German species, and as the seed is hand gathered it rarely contains any weed seeds. The purity is 80 to 87 per cent, with a germination of 85 to 98 per cent. The seed has the great advantage that it is almost entirely free from rye-grass seed, which is often an impurity in commercial red fescue seed. Experiments conducted during the last few years at St. Ives have shown that it is possible to grow forms of this fescue as a seed crop, and

limited commercial supplies, having a purity of 97·2 per cent and a germination of 95 per cent have been produced in this country. All the above forms of creeping red fescue blend well with other grasses, especially with browntop and velvet bent.

The remaining fescue obtainable commercially is Chewing's Fescue (*F. rubra* sub-sp. *fallax* Thuill.) which is a non-rhizomatous perennial species of red fescue exported from New Zealand. This species is, of course, found as a wild plant in different parts of this country, but the only seed crop taken is that in New Zealand. The plant forms a tussock, but it is of a looser type than that of the sheep's fescues. It produces both intra-vaginal and extra-vaginal shoots but all the branches ascend in the vertical direction. The species is well adapted to turf formation and blends well with species of bent and other grasses, the only disadvantage in the turf being the tendency for the leaf tips to "bleed" or discolour after cutting, and for it to lose colour somewhat during the winter months. It is, however, markedly drought-resistant. When included in seed mixtures containing *Agrostis* there is a tendency for it to be ousted by the aggressive bent. Chewing's fescue is gathered on the Waimea Plains of South Island, New Zealand, where the crop is of a semi-natural type and a considerable export trade has been built up; thus the average shipment for the years 1926 to 1933 was 780 tons per annum, of which an average of 160 tons reached the United Kingdom, 60 to 70 tons reached Canada, whilst the remainder was sold in the United States (see Fig. 29).

The story of Chewing's fescue forms a romance of the seed trade and it appears that the original seed was supplied by an English firm of seed merchants about the year 1833. It was sown near Invercargill and two years later the pasture was cut for seed. This crop was taken and sown at Mossburn, which property was later purchased by a Mr. Chewing, who harvested the fescue field and presumably marked the bags of fescue seed as "Chewing's fescue". To-day approximately 9,000 acres are harvested annually, the average yield of seed being 180 to 200 lb. per acre. The percentage purity of the seed is generally good (95 to 98 per cent), the weed seeds most commonly present being cat's-ear, rat's-tail fescue, and Yorkshire fog, but seeds of rye-grass are rarely absent and this must be regarded as a very harmful impurity. Up to a few years ago the retail price of Chewing's fescue was about 8*d.* per lb., but prices have hard-

ened and to-day it is approximately 2*s*. per lb., though it has been as high as 3*s*.

Close attention must be paid to the germination of Chewing's fescue when purchasing, for whilst the growth on leaving New Zealand may be from 90 to 95 per cent it is apt to fall during shipment, and to fall again in storage in this country. In one example, for instance, the seed germinated 95 per cent on leaving New Zealand, but had fallen to 75 per cent on arrival in England in July, while after another six months the germination was only 22 per cent, and finally after a further three months it only grew to the extent of 10 per cent. In other instances seed upon arrival has germinated only 15 per cent and is therefore useless. This matter has been so serious that the seed has unfortunately earned an ill-repute amongst seed merchants, who have often lost more money in this seed through unexpected depreciation of germination than in any other grass seed. Since Chewing's fescue is an important ingredient of seeds mixtures in this country this problem is of importance to grower and exporter alike, and Foy [8] and Hyde [9] have carried out extensive tests to investigate this drop in viability. The fall does not appear to be inevitable, because in some years the seed retained its viability remarkably well. It has been shown, however, that the falling off is associated with unfavourable conditions during shipment, such as high humidity and temperature. Further, immature seed "sweats" crossing the equator, but seed that has been well matured before exportation, and has a low moisture content, will retain its viability for some years. Foy's experiments have indicated that by artificial seed drying it is possible to overcome this rapid loss in germination, and his conclusion is that the matter has now passed the experimental stage and reached the point when it must be taken up by the industry.

It is unfortunate that the seedsman's faith in the growth-holding capacity of Chewing's fescue has been so badly shaken, because it is a desirable grass, and the market for the New Zealand producer cannot fail to be affected unless there is an improvement in this respect. The work of selecting strains of fescue and producing crops in this country, and in other parts of

[8] Foy, N. R.: "Deterioration Problems in New Zealand's Chewing's Fescue," *N.Z. Jour. Agric.*, 1934, **49,** 10.

[9] Hyde, E. O. C.: "Chewing's Fescue Seed: Influence of Temperature and Moisture Content upon Loss of Germinating Capacity," *N.Z. Jour. Agric.*, 1935, **51,** 40.

Europe, is proceeding apace, and is likely to affect the demand for Chewing's fescue in the future, since the seedsmen in this country will be less dependent upon New Zealand supplies. The sower in this country should therefore assure himself that a recent germination test has been carried out, and should not rely upon figures quoted by seedsmen, if these were taken in New Zealand before time of shipment. A germination of 70 per cent in from 7 to 10 days, with a final growth of 90 to 95 per cent in 21 days is desirable.

Before concluding references to the fescues, mention may be made of Rat's-tail Fescue (*F. myurus* L.), a species of little significance in lawn work as it is an annual, but it is occasionally found as a colonizer in long turf and small supplies of seed are at times offered. The seed is 6 mm. long, but the awn is so lengthy that the total length with awn is 15 to 20 mm. It is this peculiarity that earns the species its name.

The Bent Grasses. Amongst the bent grasses Browntop (*Agrostis tenuis* Sibth. = *A. vulgaris* With.) [10] is undoubtedly the most important. It is a slightly stoloniferous, tufted perennial found on poor, dry, acid soils in meadows, heaths, and moorlands. Some forms have short rhizomes. It is naturalized in the United States, Canada, and New Zealand, and common names applied to it include the following: Rhode Island bent, Prince Edward Island bent, Colonial bent, Waipu bent, fine bent and furzetop. To-day the main source of supply is New Zealand, to the Waipu district of which country it was transported accidentally by early settlers in 1851 to 1856 from Prince Edward Island, where it was already common. New Zealand *A. tenuis* is very similar in characteristics to the same species found in Rhode Island and Prince Edward Island (see Fig. 28).

About 20,000 acres of browntop are harvested annually in the South Otago and Canterbury regions of New Zealand, where some of the crop is certified by Government inspectors as free from redtop. Pure swards are readily secured over large tracts of country so that production costs are low. This seed is sold as Certified browntop and arrives in this country in sealed bags. Harvesting is done by a stripper and yields vary from 80 to 100 lb. per acre down to 20 to 25 lb. per acre. The export trade

[10] A fuller account of this grass appears in *Jour. Bd. Green. Res.*, 1934, III, No. 11, 200.

reached a peak of 230 tons in 1930, since when it has fallen. Great Britain takes some 50 tons per annum. It is an important grass seed and the certified grade is a high quality article with a purity that should be in the neighbourhood of 99 per cent with a germination of at least 90 per cent in 21 days. The seeds are small, being only 1·2 to 1·8 mm. long, and common impurities are species of rush, mouse-ear chickweed and yarrow. The retail price varies, but is usually about 1*s.* 6*d.* to 2*s.* per lb. The seed reaches this country during August and September.

Another type of browntop from New Zealand is found on dry soils, as distinct from moist soils more suited to the typical browntop. It is known as dryland browntop, but supplies of seed are limited. *A. tenuis* is also grown in Rhode Island, U.S.A., where 125,000 lb. were harvested in 1923 to 1924, but there has been a falling off since then. It compares favourably with New Zealand bent though little of it reaches this country. Another source is Prince Edward Island, Canada, where 15,000 lb. were harvested in 1936, though heavier yields have been obtained previously. Comparative turf plots at St. Ives show that Rhode Island bent and New Zealand bent are almost identical, and Prince Edward Island bent compares favourably in the growing season but has a poor winter colour.

The third source of *A. tenuis* is central and south-west Germany, from which a seed known as South German mixed bent is exported. As the name implies it is in reality a mixture, small amounts of *A. canina* and *A. stolonifera* var. *compacta* seed also being present. Harvesting is done by hand and the purity is about 80 per cent, thus being poorer in quality than the New Zealand bent. Germination is seldom more than 85 per cent. It sells at 2*s.* 9*d.* to 3*s.* per lb. Although this seed still reaches this country it has been very largely replaced by the better quality New Zealand bent, which is cleaner and also cheaper. Often as much as 20 per cent impurity in South German bent is chaff, but seeds of mouse-ear chickweed, yarrow and sheep's sorrel are found.

A small amount of *Agrostis* is harvested annually in this country and sold under the name of English bent.

Though found at times in lawns and proved experimentally to provide an excellent sward, no commercial supply of Velvet or Brown Bent (*A. canina* L.) is available except in small amounts harvested annually in Prince Edward Island, and this

contains some *A. tenuis*. The quantity amounted to 500 lb. in 1936, and a sample had a purity of 85 per cent (chaff 14 per cent) and germination of 90 per cent. Trials with Prince Edward Island velvet bent are in progress, but to date the turf is not so good as an indigenous selected type since there is a tendency for surface creepers to form. The winter colour, like that of Prince Edward Island *A. tenuis*, is poor. There is another form of *Agrostis canina* known as variety *mutica*, of which the seed is awnless, as distinct from the awned seed of *A. canina* proper. No commercial seed of this is available, nor does the turf appear to be so good as that formed by *A. canina*.

Very little seed of Creeping Bent (*A. stolonifera* var. *compacta* Hartm.) reaches this country, though high-quality supplies are produced in New Brunswick, Canada, where 1,300 lb. were harvested in 1936. Another source of creeping bent is the State of Oregon, where the seed is known as "Cocoos" bent, whilst a certain amount is also produced in New Zealand.[11]

Supplies of another species of *Agrostis* known as Redtop (*A. stolonifera* var. *gigantea* Koch, or *A. stolonifera* var. *major* Malte) reach this country and are used for sports purposes. Actually the commercial material, sometimes called Fiorin, is a collection of types, the plant being vigorous and forming extensive underground rhizomes. When sown alone this grass fails to make a fine sward, though the species can be included in mixtures for sports grounds. The seed is harvested in Southern Illinois, where for some forty years it has been a commercial crop. It costs about 1*s.* per lb. and should have a purity of 90 to 95 per cent and a germination of at least 90 per cent in 21 days. Unfortunately the seed is often substituted in mixtures for the seed of other bents suitable for fine turf. The assurance of the vendor on this point is desirable.

Wavy Hair-grass. In addition to the bent and fescue seeds obtainable in commerce, and forming the basis of fine seeds mixtures, there are a number of other grasses used for purposes other than fine lawns. Very like a sheep's fescue in vegetative character is Wavy Hair-grass (*Aira flexuosa* L.), a species of

[11] Fuller accounts of bents other than browntop appear in *Jour. Bd. Green. Res.*, 1934, III, No. 10, 148.

A revision of the genus *Agrostis* has been completed by W. R. Philipson, *Jour. Linn. Soc.*, 1937, LI, No. 338, 73.

limited use in greenkeeping but able to establish well on very acid soils. The species can be used in seeds mixtures for heaths and peaty soils. The leaves are dark green in colour, narrow and rolled. The seed is characterized by a twisted kneed basal awn, and tufts of white hairs, and the purity and germination rarely exceed 80 per cent. The seed is of German origin, costing about 1*s*. 3*d*. per lb.

The Meadow Grasses. Another important group of grasses used in connexion with turf formation are the meadow-grasses, or *Poas*, and the commonest and most widely distributed species amongst this group is Annual Meadow-grass (*Poa annua* L.). Its commonness is, however, due to its habit of seeding and propagating itself all the year round, but most profusely in the months of May and June. Being dwarf-growing it is adapted to close mowing, but seed when procurable is in the form of cleanings and rarely contains more than 65 to 70 per cent of pure seed. The germination of the seed rarely exceeds 85 per cent and it has only limited use on account of the impurities. One sample that was examined contained 14·4 per cent of impurities, including rough-stalked meadow-grass 4·4 per cent, perennial rye-grass 3·8 per cent, crested dog's-tail 3·2 per cent, Yorkshire fog 0·8 per cent, as well as seeds of cocksfoot, hawk's-beard and slender foxtail (see Figs. 4 and 31).

Smooth-stalked Meadow-grass (*P. pratensis* L.) is another *Poa* abundant in Britain, but only small amounts are found in fine lawns, though its presence is more frequent in grass not mown so keenly. It is very much valued in North America for pastures and for lawns under the name of Kentucky blue-grass. It is suited to the lighter soils, spreading by rhizomes, but does not reach its full development until the second year. Smooth-stalked meadow-grass can be used in conjunction with other grasses for making fairways and teeing grounds on lighter soils, as it withstands a considerable degree of treading and drought. It is a useful plant for binding slopes and banks. Commercial seed is imported from the United States, and purity should be at least 90 per cent with 5 to 7 per cent of chaff, but poorer samples have as much as 20 per cent of chaff. The germination runs from 75 to 90 per cent in 28 days. The common impurities are mouse-ear chickweed, sheep's sorrel and shepherd's purse. This species has been rather neglected in lawn work, and presents

opportunities for the plant selector. The cost is round about 1*s*. 2*d*. per lb. retail.

Rough-stalked Meadow-grass (*P. trivialis* L.), the third species of *Poa* obtainable commercially, is also abundant in this country, but is best suited to moist soils and districts. In dry places on dry lawns the foliage turns a reddish brown, but in moist fertile conditions it produces a steady yield and is quicker in development than smooth-stalked meadow-grass. It is a bottom grass and spreads by thin overground stolons, which unfortunately preclude its use on the finest turf, but it has uses for sports ground purposes. The purity should be at least 90 per cent with a laboratory germination of 90 to 95 per cent in 28 days. Yorkshire fog and mouse-ear chickweed are common impurities and the seed costs about 1*s*. 2*d*. per lb. The bulk of the commercial seed is imported from Denmark.

Wood Meadow-grass (*P. nemoralis* L.), which is indigenous to Europe, is found in woods and moist shady places, and has therefore been advocated for sowing lawns in shade. The foliage is a rich green colour, but supplies of seed are limited and the cost from 3*s*. 6*d*. to 6*s*. per lb. according to season. The seed is produced in Germany and Holland and owing to its scarcity it is subject to adulteration. Good seed should not contain more than 10 per cent of chaff and 1 per cent of weed seeds, and it should have a germination of about 85 per cent in 28 days.

Another meadow-grass is Flat-stemmed Meadow-grass (*P. compressa* L.), which although indigenous to Great Britain is seldom found in turf. Commercial seed is produced in Canada, where it is well established, under the name of Canada bluegrass. South Ontario is the seed-producing area. In turf it forms a tough coarse sward, but its possibilities in this country have not been fully investigated. It spreads by underground rhizomes.

As a curiosity Bulbous Meadow-grass (*P. bulbosa* L.), which is found on some seaside golf courses in this country, is worth mentioning. Commercial "seed" from America is actually in the form of small bulbils, produced on the flowering stems in place of seed. The species has little value for turf formation, though its uses in the hotter parts of the South of France have been investigated and have shown fairly satisfactory results.

Perennial Rye-grass. It remains to describe in this chapter two groups of grasses of more particular use for second-class lawns,

and the sowing down of large areas like sports fields. The first of these is Perennial Rye-grass (*Lolium perenne* L.), which is a tufted perennial abundant on most soils and grows best on moist fertile land. Its value is reduced on dry soils. It has an extensive use in agriculture and is reasonably permanent on the richer soils, though unsuccessful under acid conditions or at high elevations (Fig. 32). There are many varieties or strains, and some of the old varieties, described as Pacey's or Devon Evergreen have now lost much of their identity and these terms are now applied to the genuine perennial rye-grass. Indigenous strains are produced largely in Kent, where the seed is harvested with wild white clover from old pastures and recovered from the cleanings. The plant reaches its maximum growth in the second year, and being vigorous it checks weed invasion on newly-sown land. It is more persistent and more leafy than the ordinary types of rye-grass. A number of seed merchants offer this, or "once-grown" indigenous rye-grass, which is the Kentish old pasture seed grown as a seed crop. They also offer their own selections, and the Welsh Plant Breeding Station has placed on the market a selection known as S.23, which is noted for its leafiness and persistency. Tests with it for turf purposes are in progress.

The ordinary commercial perennial rye-grass is shorter lived than the indigenous type and is produced mainly in Northern Ireland and to a lesser extent in Ayrshire. Some 100,000 acres are grown annually in Northern Ireland, yielding 5 to 6 cwt. of seed per acre, which is then graded according to bushel weight, a good sample having a bushel weight of 27 to 28 lb. The small seeds are often graded out and sold as "small" or "short-seeded" perennial rye-grass, which has a higher bushel weight of 30 to 32 lb. The purity of rye-grass should be 98 to 99 per cent, with a growth of 85 to 95 per cent in 14 days. The cost of Kentish Indigenous rye-grass is from 1*s.* 6*d.* to 2*s.* per lb., "once-grown" about 1*s.*, and ordinary rye-grass 5*d.* per lb. retail.

Other strains of rye-grass are produced in Denmark and Sweden from selections made by plant breeders, and there is a form that is certified and exported from New Zealand. This type is persistent, but the ordinary New Zealand rye-grasses are less persistent in this country than the British.

Crested Dog's-tail. The remaining species requiring reference is Crested Dog's-tail (*Cynosurus cristatus* L.), found naturally on

dry hill pastures and even on heavy clays. It withstands drought and cold, but is slow in developing, only reaching its maximum in the second year. The plant grows in tufts with the leaves at the base and is essentially a bottom grass, and being tough in nature is used in mixtures requiring hard wear. Commercial seed is produced in Northern Ireland and New Zealand and should have a purity of 96 to 99 per cent, with a growth of 80 to 90 per cent in 28 days. In buying seeds it is advisable to avoid those of a canary-yellow colour because these are usually immature seeds of poor vitality. The experiments of Jacques and Corkill [12] have shown that high germination is coincident with maturity of the seed, and this condition is linked with seed colour, which is a dull brown in mature seeds. It has also been shown that loss of germination during shipment from New Zealand can be related to the immaturity of the seed.

[12] *Jour. Min. Agric.*, 1932, XXXIX, 115.

Chapter Eight

Choice of Seeds Mixture and Rate of Sowing

It has already been pointed out that the number of grass species contributing to the herbage of a fine lawn is decidedly limited, and the same will be found for golf and bowling greens, and even golf fairways and sports grounds. The latter may be composed of comparatively large numbers of miscellaneous plants, but usually well over 70 per cent of the turf will consist of two or three species. On swards consisting of the finest turf, bent, or a perfect blend of bent and fescue, may account for almost 100 per cent of the herbage. The conditions imposed on a fine lawn are very uniform, though very exacting, as compared with a pasture or a meadow, but this very uniformity and definiteness permits the choice of a seeds mixture consisting of species most suitable in meeting the precise demands. In agricultural practice some 30 to 40 years ago it was not uncommon to include 20 species in a grass-land mixture, but to-day rarely more than 8 or 10 are utilized, and there is a tendency to further simplification. Knowledge of seeds mixtures for fine turf purposes has advanced in a similar direction and it has been shown that the simpler mixtures, composed only of species suited to the definite requirements, are best. In fact, to include a large number of species in a lawn or green mixture is to invite eventual disaster, because the least desirable grasses may flourish exceedingly and crowd out or severely hamper those that are especially desired; colonization in patches and unevenness through some plants failing to knit may also occur, and, finally, the inclusion of unnecessary species involves waste of money.

The seeds mixture must, therefore, be simple and it must consist of species capable of intermingling to form a uniform

sward. Blending is most important, but will not be achieved if two markedly stoloniferous strains or species of grass are sown together, since the tendency will be for each to colonize large areas of ground, some of them consisting almost wholly of one and some of the other. The resultant effect of such a condition would be a network of patches, an effect found in greens sown with mixed strains of bent, or sodded with turf containing mixed strains. If, therefore, two or more strains or species are to be used in a mixture they should consist of strains or species that are not markedly stoloniferous. On the other hand, if a green of one species is desired, then it would appear essential that it should consist of a stoloniferous strain selected to suit the conditions, without the aid of other species, and planted as a pure culture, as is done in vegetative planting. A mixture for use in sowing a fine lawn (and these remarks also cover putting greens, croquet lawns and such-like), need only contain two or three species, and these should be selected from among the bents and fescues commercially available.

Experiments at St. Ives have shown that the following simple mixture satisfies the conditions, giving good intermingling and a uniform sward:

7	parts	by	weight	Chewing's Fescue
3	„	„	„	New Zealand Browntop

Chewing's fescue is non-rhizomatous and the browntop rarely forms more than short stolons. On better soils there is a tendency for the bent—the aggressive partner in this mixture—to oust the fescue, but by controlling the fertility this may largely be checked, since fescue is more tolerant of poorer soil conditions. An example of this may be seen on excavated lawns that have been sown with such a mixture. Here the bent tends to predominate in the deeper "filled" soil, whilst the fescue assumes an ascendancy in the part "drawn" and covered with less soil. Some lawn owners prefer the more leafy sward of bent while others prefer the wiry and bristly sward of the fescue. For putting, a turf of Chewing's fescue is faster than one of browntop. If desired the mixture given above may be made more favourable to fescue by increasing the Chewing's fescue to 9 parts and reducing the browntop to 1 part; but even if only 5 per cent of bent is included in a mixture it often happens that the fescue will gradually disappear under the effects of

keen mowing and the influence of systematic dressing. South German bent as the source of bent (*Agrostis*), is not suggested for the finest turf mixtures, though it may be used on coarser swards, because comparative trials have shown it to be less uniform than New Zealand browntop, and as it contains some *A. stolonifera* there is the possibility of patches developing in the turf.

Good lawns can be formed from either Chewing's fescue or New Zealand browntop sown alone, but, the bent seedlings being small, the rate of establishment of a pure bent lawn is apt to be slow, and so in practice it is better to sow a mixture, with the quick-growing fescue acting as a "nurse" in the early stages. Some experimental work by Madden [13] in New Zealand has shown the advantage of this practice in aiding weed suppression and giving better initial ground cover. The figures obtained by this worker are given in the table below, and reference will be made later to Column 4.

Area of Ground covered by Grasses and Weeds

	Browntop —pure (1)	Chewing's fescue—pure (2)	Browntop and Chewing's fescue 1 : 2 (3)	Browntop, Chewing's fescue, and rye-grass 1 : 2 : 2 (4)
	per cent	per cent	per cent	per cent
Bare Ground	13·0	12·0	6·0	19·0
Browntop	56·6	1·8*	32·6	3·3
Chewing's fescue	—	62·6	51·8	18·2
Perennial rye-grass	—	—	—	53·7
Weeds	30·4	23·6	9·6	5·8
	100·0	100·0	100·0	100·0

* Volunteer (not sown).

In seasons when the seed of Chewing's fescue is unreliable as regards viability, the inclusion of Creeping Red fescue is advised in the following proportions:

3 parts Chewing's Fescue
4 ,, Creeping Red Fescue
3 ,, New Zealand Browntop

[13] Madden, E. A.: Bull. No. 165, N.Z. Dept. of Agric., 1935.

The substitution of hand-gathered fescue (*F. glaucescens*) from sea marshes for the creeping fescue is permissible, especially if the latter contains any seed of rye-grass. Or, if desired, a selected strain from the above, like the St. Ives creeping red fescue may be utilized. Likewise the Aberystwyth red fescue strain S.59 may be employed, since recent trials have shown that it blends well with the other fescues and the bent in a closely-mown sward. Part of the fescue may also be included as fine-leaved fescue, especially on rather acid or peaty soils, and in years when hard fescue is cheaper than Chewing's fescue, this species may be employed for making a cheaper non-rye-grass mixture, though the resultant turf is not so satisfactory. Recent trials have also shown that good results can be obtained when velvet bent is used with Chewing's fescue, in place of New Zealand browntop, but there is the tendency one would expect from a creeping form of this type to dominate the sward rapidly to the exclusion of the fescue.

It may be argued that the above simple seeds mixtures are insufficient to meet the wide range of soils likely to be encountered in different parts of the country. It should be noted, however, that mixtures of these types have been satisfactorily employed under a wide range of soil conditions, but in any event the view is expressed that it is preferable when sowing a lawn to modify the soil to a medium loam consistency rather than "juggle" with the seeds mixture in an effort to suit existing conditions. This has been stressed in the chapter dealing with the preparation of the site for sowing. For larger areas it may not be possible to modify the soil materially in this manner, but here the conditions are usually less exacting and a more comprehensive seeds mixture may be chosen; even so the basis of the mixture should be bent and fescue. Hard and fast rules in devising a seeds mixture for large areas can hardly be laid down, since local conditions and the purpose for which the lawn is intended must always have a deciding influence, to say nothing of the funds available.

In spite of the findings of present-day greenkeeping research, many proprietary seeds mixtures for fine lawns still contain as many as 8 or 10 species, and whilst there are no doubt widely-differing views on this matter, it is difficult to understand on what basis such mixtures have been compounded. In some instances there is little doubt that the mixtures are made up

for the purpose of maintaining a standard catalogue price, and the occasional changes in the composition of these mixtures are designed to counterbalance the fluctuations in the market prices of the ingredients.

As is generally known, there are two types of seeds mixtures commonly used, namely rye-grass mixtures and those containing no rye-grass. It is usual to include some 50 to 60 per cent of ordinary commercial perennial rye-grass in proprietary rye-grass mixtures, and this undoubtedly leads to rapid establishment and quick cover. If such mixtures contained in addition 40 to 50 per cent of bent and fescue there might be some chance of the lawn becoming established eventually, but as the mixtures usually contain only 1 to 5 per cent of bent and 10 to 20 per cent of fescue, these species are almost smothered out from the beginning. Then, as the rye-grass dies out under the influence of mowing, a bare open turf results, which forms a happy resting-place for weed seeds. The only advantage of such rye-grass mixtures is their cheapness and the fact that they form a quick cover. They do also, as is shown by the figures obtained by Madden in the table above, result in slightly better initial weed smother, but the ultimate turf formed is sparse and not permanent.

It may sometimes be desired to maintain a more permanent rye-grass sward, and for this purpose the Kentish indigenous rye-grass may be used or a selected strain such as S.23 in the Aberystwyth series. These leafy strains are slower to establish but are more persistent under the mower. They are less objectionable than the ordinary rye-grass as far as stalk production is concerned, though on light soils all strains are likely to be less leafy and more stalky.

Mixtures free from rye-grass, yet lower in price than those containing bent and fescue only, may be made up by including crested dog's-tail, smooth-stalked meadow-grass, and wavy hair-grass, with reduced amounts of bent and fescue, but whilst these are very useful mixtures they do not produce a sward approaching the standard of pure bent and fescue mixtures. They should be avoided if the best results are required. Rye-grass mixtures must not be sown if a fine lawn is desired, and even for first-class hockey grounds, cricket out-fields, or golf fairways they are not to be preferred. The only occasion when they must be used for this type of sward

is when consideration of cost definitely precludes a better article (see Fig. 3).

Whilst it is impossible to lay down hard and fast rules in seeds mixtures for extreme conditions of soil, certain modifications are possible; thus, on very acid soils some of the red fescue may be substituted by fine-leaved fescue, and on dry sandy soil the proportion of fescue may be increased at the expense of the bent and smooth-stalked meadow-grass included. In shady situations it is usual to include wood meadow-grass and rough-stalked meadow-grass, whilst the latter species is also useful on moist rich soils where a fine turf is not needed. On acid soils part of the fescue may also be substituted by wavy hair-grass, and for rough turf part of the bent may be replaced by redtop. Crested dog's-tail, though a useful species, and having the merit of being tough and hard-wearing, should not be included in fine mixtures except on chalk soils and in dry situations.

The inclusion of clover in seeds mixtures for large areas is sometimes considered, and if desired, then wild white clover of indigenous strain should be used. On poor gravelly soils yellow suckling clover is sometimes useful, whilst on calcareous soils bird's-foot trefoil forms a drought-resistant legume to include as part of the mixture.

The seed rate to be used in sowing down new turf depends upon (1) the composition of the seeds mixture; (2) the cleanness and tilth of the land; (3) the purpose of the sward, and (4) how soon the turf is required. For putting greens, and best quality turf of this type, required as soon as possible, it is usual to sow 2 oz. of bent and fescue mixtures per sq. yd. This assumes seed of high quality. Where bent alone is being sown, the rate should not exceed 1 oz. per sq. yd., though as little as $\frac{1}{8}$ oz. per sq. yd. has given satisfactory, but slower results, on clean land. Experiments have been carried out in an attempt to cut down the seed rate very materially in view of the high cost of fine seed. In one trial the bent and fescue seed were sown separately in opposite directions in narrow drills 3 in. apart, and whilst good turf was soon established in this way at a rate of 40 to 50 lb. per acre, no better result was obtained than with 40 lb. of bent seed sown broadcast with a distributor in the ordinary manner. The advantage of making heavy sowings of seed lies in quick establishment, and greater smothering of any

weeds that may have survived the fallowing period, and therefore when sowing at very light rates it is doubly important that the land should be well cleaned. For golf fairways, for example, sowing at a rate greater than ¾ to 1 oz. per sq. yd. would usually be impossible on account of cost. With rye-grass mixtures, from ½ to 1 oz. per sq. yd. of seed may be used.

Chapter Nine

The Purchase of Grass Seeds

he owner of a small lawn usually relies for his supplies of seed upon ready-prepared mixtures bought from a seedsman, many of whom put on the market mixtures under names borrowed from well-known sports clubs or stately mansions, the inference being that the seeds will give a turf equivalent in quality to that found at the place named on the packet. The results may or may not come up to the standard expected. It would be much more interesting for the purchaser to buy seeds by name, separately, and with due inquiry as to quality and price just as he is accustomed to buy flower seeds or bulbs. It would at least enable him to repeat the same mixture. Lawn owners, however, who wish to avoid this small extra trouble by purchasing ready-made mixtures should deal with a reliable seed house, because there is no provision in the Seeds Act requiring a merchant to conform to a standard of quality for lawn-seed mixtures sold as such.

In this connexion an example may be quoted of a lawn seed sold without a declaration by a multiple store at 1*s*. 4*d*. per lb. Analysis showed a purity of only 92·7 per cent, the impurities consisting of 6·3 per cent of chaff and 1 per cent of harmful weed seeds. Of the grasses present, 56 per cent was ordinary perennial rye-grass, the balance being seed of dog's-tail and some of the finer grasses. Such a mixture is incapable of making a permanent lawn, and if bought to formula by name, would have cost 9*d*. to 1*s*. per lb. Actually a non-rye-grass mixture consisting of Chewing's fescue and New Zealand browntop, of high purity and germination and capable of forming a permanent lawn, could have been bought for 1*s*. 6*d*. to 1*s*. 9*d*. per lb.

The practice of using hay-loft sweepings cannot be too

strongly condemned. They are little more than cleanings and a sample recently examined contained 44 per cent of rye-grass (only 53 per cent of this was viable), 50 per cent of chaff, and 6 per cent of weed seeds, many very harmful in turf. Cleanings are also apt to contain clover seeds.

If the best value is to be obtained for money spent then it is necessary that the ingredients of the seeds mixture should be purchased by name, and a study made of the quality of the samples. It is not sufficient to ask merely for so many pounds of a certain seed, but due inquiry must be made as to whether it is *good* seed. To be good seed the sample must fulfil certain requirements, which may be summarized as follows:

(1) It must contain a high proportion of viable seed capable of strong growth;

(2) It must be free from the seeds of weeds capable of establishing themselves in the lawn;

(3) It must be reasonably free from inert matter, such as chaff or dirt; and

(4) It must represent the species or variety of that species shown on the label attached to the container.

The first three points are amenable to laboratory test but it is not possible by a laboratory test (though it might be possible after a time as a result of growing a sample) to give the final verdict on the last point, so that here the purchaser has to rely very largely on the integrity of the merchant. If deemed necessary a sample of the seed offered can be tested on payment of a comparatively small fee at one of the Official Seed-Testing Stations, and the report of the analysis, which is for private use only, will declare (1) the germination, i.e. the viability or percentage of numbers of pure named seeds that are alive; (2) the purity, i.e. the percentage of the sample by weight which consists of pure named seed, dead or alive; and (3) a statement of the chaff and weed impurities. Interim reports are submitted which show the speed of germination. A comparison can then be made between different lots of seed offered, for by a simple calculation the samples can be reduced to a common denominator by using for each the following formula:

$$\frac{\text{Germination per cent} \times \text{purity per cent}}{100} = \text{“real value”}.$$

A comparison of the “real value” in relation to the price

quoted at once shows which seed is the best value for money; but, the "real value" may be misleading unless due regard is paid to the nature of the weed impurities present. It is necessary, therefore, to examine the seed analysis in more detail, and below are given two laboratory analyses of seeds to bring out these points:

	No. 1	No. 2
	per cent	per cent
Purity	99·5	95·0
Germination	98·0	98·0
Amount of impurity		
Nature of impurity:		
Chaff	0·4	all chaff
Yorkshire fog	0·1	
Price per lb.	2*s.*	2*s.* 4*d.*
Real value	97·5 per cent	93·1 per cent

If sample No. 1 were accepted on the basis of its real value alone it would appear to be considerably better than sample No. 2 with only 95 per cent purity and the same germination as No. 1. Further detailed examination of the analyses, however, shows that the 5 per cent impurity in No. 2 sample is merely chaff, whereas in No. 1 sample 0·1 per cent of the impurity is Yorkshire fog. Therefore, although sample No. 2 has rather fewer seeds of the named variety and costs slightly more, it is the better sample of the two and should be purchased. Too much importance should not be attached to differences of 2 or 3 per cent in the germination of a sample, but seed germinating below 75 per cent under laboratory conditions (depending on the species) is likely to establish poorly in soil, since many of the seeds are likely to be weaklings and incapable of producing strong plants. A large increase in seed rate, to allow for low germination, cannot therefore be relied upon to give a satisfactory take. When buying seed separately by name, it is important to purchase that which is plump and which is therefore likely to establish better than small, shrivelled, light seed. Seed with a musty odour and dirty colour should be regarded with suspicion.

The danger from weed impurities in fine turf seeds may be

further emphasized by a consideration of the numbers of weed seeds involved. Thus, when a percentage by weight of an impurity is stated, this represents a large number of actual seeds. The table below shows that if 2 oz. of grass seed containing 0·2 per cent of the following impurities were sown on 1 sq. yd., then the number of foreign seeds introduced would be as shown in the right-hand column:

Botanical Name of Species	Common Name of Species	No. of Seeds per sq. yd.
Cynosurus cristatus L. . . .	Crested Dog's-tail	245
Holcus lanatus L. (in glumes)	Yorkshire Fog	230
Lolium perenne L.	Perennial Rye-grass	57
Poa annua L.	Annual Meadow-grass	370
Achillea millefolium L. . . .	Yarrow or Milfoil	710
Cerastium vulgatum L. . . .	Mouse-ear Chickweed	1,110
Plantago lanceolata L. . . .	Ribwort Plantain	87
Hypochœris radicata L. . . .	Cat's-ear	145
Rumex acetosella L. . . .	Sheep's Sorrel	190
Trifolium repens L. . . .	White Clover	70

A practical example of the effects of sowing seed containing as little as 0·1 per cent by weight of Yorkshire fog may be seen in the following figures obtained on a 3-year-old fescue sward at St. Ives:

Plot No.	Purity of Seed per cent	Percentage of Ground covered by Yorkshire Fog
	97·7 (no Yorkshire fog)	1·0
	92·6 (0·1% Yorkshire fog)	20·0
	98·5 (no Yorkshire fog)	nil
	98·6 (no Yorkshire fog)	2·5

It will be seen that although a small percentage of Yorkshire fog may be attributed to dormant seed in the soil the presence of 0·1 per cent in the seed has led to 20 per cent of the ground being colonized by this undesirable grass (see Fig. 5).

The following table shows a comparison of the effects of sowing impure bent as against using a pure sample (all figures per cent):

Seed		Percentage of Ground covered in Turf after 12 months			
Purity of Bent	Impurities	Bent	Yorkshire Fog	Crested Dog's-tail	Bare Ground and other Species*
99·1	Chaff and dirt 0·9	83	—	—	17
91·7	Yorkshire fog and dog's tail 1·6; Chaff and dirt 6·7	63	20·5	1·5	15

*Derived from the soil.

It will be obvious from these examples that even small quantities of impurities may lead to very serious after-effects that will involve the lawn owner in expenses and much annoyance. The matter is of far greater importance for the sower of fine turf than for the farmer because a common seed rate for lawns is 6 cwt. per acre as compared with 25 to 40 lb. per acre for the farmer. When purchasing seed the point to remember is *how many* impurities will there be on, say, 1 sq. yd. of the finished turf.

The Seeds Act, 1920,[14] and the regulations prescribed under it are not designed to give the purchaser of lawn seed the information required, but it is desirable that those who purchase grass seed, especially large buyers for large lawns, golf courses, or sports grounds, should have a general knowledge of the principles underlying the Act as well as the particulars supplied by the Official Seed-Testing Stations set up to give effect to the Act.

The order of the Ministry of Food which eventually became the Seeds Act, 1920, was originally introduced to give the sowers of agricultural and horticultural seeds a knowledge of the analytical purity and growth of the seeds they were sowing; among other things a list of the species of seeds controlled is scheduled in the Regulations under the Act. These seeds must be tested and the particulars declared to the customer by the seller, in writing, at the time of sale or after the sale. This obligation placed on the sellers of seed is in general practice in this country to-day, and as already stated earlier in this chapter, lawn seed is not included under the Act. It is, how-

[14] Seeds Act, 1920, and Seeds Regulations, 1922: H.M. Stationery Office.

ever, safe to say that most reputable seed houses have accurate tests made of all seeds used for this purpose and are ready to give the particulars in any quotation for which they are asked, if requested to do so.

When a sample of seed is submitted to a Testing Station, an analysis of purity is made first of all and the impurities are grouped under four headings for making the return, viz.: (1) injurious weeds; (2) other weeds; (3) useful species, and (4) inert matter. In accordance with the Seeds Act, 1920, the injurious weed seeds are docks and sorrels, cranesbills, wild carrot, Yorkshire fog and brome grasses. When more than 2 per cent of these weeds are present in a sample of grass the fact must be declared by the seller. Moreover, the Act makes it illegal to sell or "knowingly to sow" seed containing more than 5 per cent by weight of such injurious weed seeds. The sample is next subjected to the germination test to determine the growth of pure seed, and an interim report, which records the speed of germination, is then made, as well as a final report (after 10, 14, 21, or 28 days according to species).

The Act does not cover seeds sold as lawn seeds, neither are individual species like the fescues and bents included in the regulations. If, for example, a sample of Chewing's fescue is analysed and found to contain amongst its impurities 0·2 per cent of rye-grass this item would be returned as a "useful species". We have already shown that a sowing of fescue at 2 oz. per sq. yd. containing this amount of rye-grass impurity would result in 57 seeds of this unwanted grass falling on one square yard of soil.

A tentative outline plan [15] has been put forward for surmounting this difficulty, and it has also been suggested that impurities like rye-grass and Yorkshire fog might be recorded separately in numbers per unit weight of sample, say 1 or 2 oz. Some seed houses have, indeed, shown a willingness to do this and undoubtedly if the public requested this information, seedsmen would meet the demand.

[15] *Jour. Bd. Green. Res.*, 1931, II, No. 5, 125.

Fig. 9.—An experimental green made of velvet bent (*Agrostis canina*).

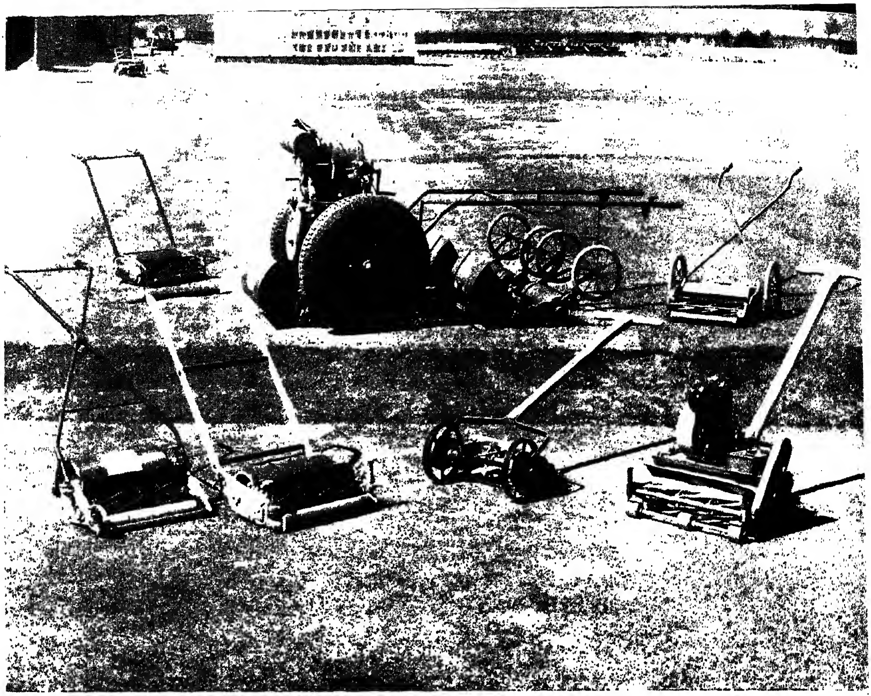
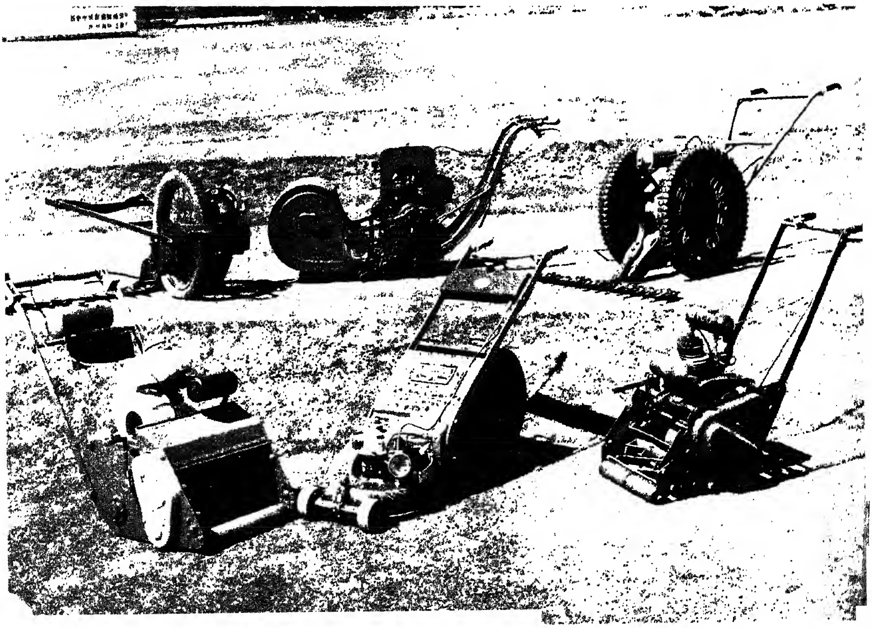


Fig. 10 (*above*).—Types of mowing machines for golf greens, bowling greens and fine lawns.

Fig. 11 (*below*).—Types of mowers and reapers for large lawns, sports grounds and long grass.



Chapter Ten

Sowing Seeds and Treating the New Sward

Having prepared a fine seed bed and satisfied oneself that fallowing has been adequate, sowing of the grass seeds may commence. It is important, however, again to stress the need for patience and care in dealing with the last stages of preparation, and the futility of going to a great deal of trouble with the soil and then sowing seed containing injurious weed seeds, or conversely failing to prepare the soil satisfactorily and then sowing an expensive seed. Either will bring poor results, if not failure.

Even though a very good seed bed has been produced, it is often advisable, especially on soils known to be poor, to carry out some pre-treatment, and the following figures, obtained by Madden [16a] in the course of experiments conducted by the New Zealand Board of Greenkeeping Research are of interest in this connexion. They show the advantage of using a quick-acting

Table Showing Percentage of Sward in Grass, Weed and Bare Ground (sward 6 months old)

	Quick-acting Fertilizers	Slow-acting Fertilizers	No Fertilizer
Bare ground	8·0	17·0	32·0
Sown grasses:			
Browntop and Chewing's fescue	89·5	71·6	54·8
Weeds and Clover . . .	2·5	11·4	13·2
	100·0	100·0	100·0

[a] Madden, E. A.: Bull. No. 165, N.Z. Dept. of Agric., 1935.

fertilizer mixture of nitrogen and phosphate as against a slow-acting mixture of these plant foods, or no pre-treatment at all. Sulphate of ammonia and superphosphate were used as the quick-acting fertilizers.

As a practical recommendation the following mixture may be raked into the soil 10 days before sowing:

½ oz.	per	sq.	yd.	sulphate of ammonia
1	,,	,,	,,	superphosphate
¼	,,	,,	,,	sulphate of potash

Pre-treatment with lime before sowing is not recommended unless there are obvious indications of high acidity and lime deficiency; this matter receives further attention in Chapter 19. Where there are no obvious signs of lime deficiency then the above general fertilizer will give the required fillip.

Another pre-treatment of the seed bed, which has received some attention, is that of lead arsenate applied at from 1½ to 2 oz. per sq. yd., its purpose being to control grubs such as leather jackets, and earthworms, which may be present or which may subsequently invade the new sward. The effect upon germination when lead arsenate is applied to the soil before sowing has been the subject of experiments, and preliminary data [16b] show that the percentage germination of the following species was not affected: perennial rye-grass, creeping red fescue (two forms), Chewing's fescue, rough-stalked meadow-grass, smooth-stalked meadow-grass, annual meadow-grass, crested dog's-tail, browntop, and velvet bent. The subsequent growth of the grasses was satisfactory, though vigour was slightly less in treated soil as against untreated as regards browntop, crested dog's-tail, rough-stalked meadow-grass, annual meadow-grass, and one form of creeping red fescue. With the other species the lead arsenate appeared, if anything, to have favoured growth as compared with the controls. In the light of these experiments it would appear that further investigations on the prevention of this slight loss of vigour should be carried out before this method can be recommended without reserve.

Discussion frequently takes place as to the best time of the year at which to sow seed, but generally speaking there are two suitable periods of the year—the spring and late summer or early autumn. Experience has shown that late summer sowing,

[16b] *Journ. Bd. Green. Res.*, 1938, V, No. 19, 274.

about the end of August in northern or colder parts of the country, and early September in the warmer and more southerly parts will achieve success. This time of sowing provides a longer period of suitable weather for fallowing the soil, because before spring sowing there may not have been sufficient moist, warm weather to ensure a good germination of weed seeds. Spring sowings usually contain more weed plants than autumn sowings. If the seedlings are well established in the autumn they are ready to go right ahead at the onset of spring weather. Further, there is less likely to be winter kill of seedlings in the cold weather following an autumn sowing than through the effects of desiccation in summer drought after spring sowing. It is a mistake, however, to sow grasses late in September and even in October as is sometimes done because under these conditions there may be poor germination and even failure through winter kill. This is particularly true of bent seedlings, which are very small in the early stages and may be beaten down and gradually destroyed. Fescue, on the other hand, is more tolerant of late seeding and should be used predominantly for late sowings.

Broadcast sowing by hand is quite satisfactory provided certain elementary precautions are adopted. Uniform sowing is important because it results in a more satisfactory sward, and, of course, if the seedlings are regularly spaced they are better able to compete against any weed aggression which may take place. It is customary to divide the quantity of seed available into two lots of equal weight and sow in opposite directions. Greater evenness can be obtained, however, by dividing the area to be sown into a number of spaces and dividing the seed into double this number of equal small lots. Each space is then sown in cross directions (see Fig. 6).

On large areas some mechanical means of sowing is necessary, and perhaps the most popular method is to use the fiddle seeder. Experiments have shown, however, that some of the small distributors made for applying fertilizers to turf can conveniently be adapted for sowing seeds. Thus, using a 36-in. fertilizer distributor of the moving band type, it was possible to sow evenly as little as 40 lb. of bent seed per acre. It was necessary in this test to add sufficient fine compost to the seed to ensure a combined rate of 1 oz. per sq. yd. (300 lb. per acre), as this was the lowest rate to which the machine could be set. Finely screened dry soil or sand and soil or even sawdust could

equally well be used. It was found advisable to test the machine on a floor or tarpaulin to check the setting (see Fig. 27).

Sowing should take place on a still, quiet day, and always when the surface of the soil is dry. The seed should be sown on a raked surface, and then be very lightly raked in—a wire rake is useful—but deep covering is not to be recommended. Experiments have shown that the amount of added covering over newly-sown seed determines to a large extent the degree of establishment. The following table will make this clear:

Table Showing Percentage Establishment per 100 Viable Seeds

	Seed raked in and lightly covered	Seed raked in and *not* covered
New Zealand browntop	11	39
Chewing's fescue	74	68
Fine-leaved fescue	54	52

These figures can be correlated with seed size, for when small seeds like bent are covered there is a tendency for the soil to cake over the surface and smother the young seedlings, so that establishment is prevented. With fescues, however, the seeds are larger and tend to lie on the surface, so failing to obtain the right conditions for germination and growth; when covered, therefore, rather better establishment is obtained.

In sowing pure bent, therefore, covering is not required, but with fescue there is an advantage in covering. In practice mixtures of fescue and bent are usually employed, and here a light covering at no more than 2 lb. of fine soil or compost per sq. yd. should be given. Where fescue alone is used from 3 to 4 lb. per sq. yd. may be applied. In large-scale sowings light harrowing after sowing, followed by rolling, is necessary, but it is impracticable to cover with a special dressing.

After sowing the lawn, light rolling, if the surface is dry enough not to cling to the roller, may be done on light and medium soils, but on heavy soils it is preferable to omit this operation as caking of the surface reduces establishment. Leaving the soil somewhat rough after sowing provides some degree of shelter to young seedlings, especially bent.

The figures given above show also the low rate of establish-

ment for bent, and illustrate the point that even if the seed germinates 100 per cent in the laboratory, not all the seedlings will make mature plants on the lawn.

In proximity to towns, trouble from birds (especially sparrows) is common on newly-sown lawns. A network of black cotton or strips of rag or tin tied to lengths of twine may be used as a scare. The seed may also be moistened with paraffin oil and dusted with red lead—a treatment harmless to the seed yet sufficient to prevent bird depredations.

Given good germinating weather the seedlings should braird in from 5 to 10 days and will make rapid growth. It is at this point that great care is required in establishing a sward and the discretion of the lawn owner or greenkeeper must be fully exercised. If an early autumn sowing has been made it is probable that before the onset of wintry weather sufficient growth will take place to call for one cutting. This should be done when the grass is about 2 in. high, using a side wheel machine, but before topping is carried out it is advisable to scatter any earthworm casts with a bamboo rod and to roll the lawn once or twice with a medium-weight roller. The blade of the mower should then be set so that it removes about half the leafage; keen mowing must at all costs be avoided. Following an autumn sowing, top dressing may be carried out with compost about February, and as spring advances the frequency and intensity of the mowing may be gradually increased. Spring fertilizer treatment may be required, but it is wise to "nurse" the grass at this stage and to allow it to become well established before cutting too keenly.

Newly-sown grass is very apt to damp off with the fungus *Pythium*, especially when seeds are sown at the end of the autumn sowing period, when moist, muggy conditions may be experienced. The grass may be assisted through the critical period by a light dressing of sulphate of ammonia or ammonium phosphate, or by spraying with a solution of Cheshunt compound. Seedlings of bent may be attacked by another fungus, *Olpidium agrostidis*,[17] which causes a form of damping off. It forms small cysts on the roots of the grasses. The fungus *Cladochytrium cæspitis*[18] also causes damping off of bent seedlings, but little information exists as to its control, though in some

[17] Sampson, K.: *Jour. Bd. Green. Res.*, 1933, III, No. 8, 32.
[18] Ivemey-Cook, W. R.: *Jour. Bd. Green. Res.*, 1937, V, No. 16, 18.

preliminary tests the use of a solution of sulphate of iron was successful in checking its spread.

Even though great care has been taken in preparing a seed bed and in the choice of clean seed, it may happen that a number of weeds appear in the newly-sown turf; these will, however, usually be found to be annual weeds that have blown into the soil at the time of sowing, or have been introduced by careless use of contaminated top-dressing, or have even survived the fallowing period. There is no need for alarm about annual weeds though if the grass is weak and poorly established, plants like common chickweed (*Stellaria media*) may grow more rapidly than the sown grass, so tending to smother it before cutting can commence. Annuals like chickweed, shepherd's purse, mayweed, and groundsel gradually die out as a result of regular mowing, but if very plentiful their removal by hand picking is advised. It sometimes occurs that the amateur, seeing a number of annual weeds in his lawn, immediately jumps to the conclusion that the seedsman has sold him impure seed, forgetting or being unaware that the seeds of annual weeds are rarely found in good grass seeds because they are removed by the cleaning machinery. It is much more important for the lawn owner to concern himself with the removal of adventitious plants of perennial rye-grass, cocksfoot, or Yorkshire fog, introduced with the seed or more probably already present in the soil; these, especially the last species, tend to persist in the mature lawn in spite of the mowing. A frequent cause of difficulty in newly-sown turf is the presence of annual meadow-grass, but if the soil has been well fallowed the amount of this will be so small that it will be possible to remove it in the early stages.

Recently there has been introduced a method of sowing lawns in which the seeds are "pre-sown". That is, they are arranged in parallel rows between two sheets of a thin paper-like vegetable medium, obtainable by the yard in 2 ft. widths. It is claimed that more uniform spacing of the seed, more uniform burying, less bird damage and better conditions for germination result from this method. Within two or three weeks of planting, the paper medium has decomposed. Seeds mixtures for different purposes and qualities of turf are obtainable. The cost is rather more per sq. yd. than using the seed in the broadcast manner and it remains to be seen whether the better establish-

ment claimed by the manufacturers justifies the additional expense. Comparative trials using the "pre-sown" method alongside ordinary broadcast sowing have not shown any special advantages. The "pre-sown" method took longer to lay down than the broadcast. Whilst the method may have a future for small lawns, or for sowing banks, it is difficult to imagine large areas like golf greens or fairways being sown down. The method is likely to prove difficult on undulating surfaces and in high wind.

Chapter Eleven

Making Verges and Banks

The establishment and maintenance of grass verges is always a difficult proposition in a garden and unless it is properly carried out is best left alone, because nothing looks worse than a ragged edge with broken pieces and bare spots surrounding the bedding display. On the other hand, a neatly-kept verge shows off the floral display to best advantage. In making new verges it is important to allow sufficient width to take the mower conveniently, and the edges should be regular and arranged 2 to 3 in. above the borders or adjacent paths. To get the best results a series of level pegs and narrow wood straight-edges should be used to find the right level and to enable the intervening space to be built up with soil. Whether the verge is to be sown or sodded makes little difference at this stage, though if sods are to be planted the level will be proportionately lower. A straight-edge should also be used at right angles to the length of the verge for the purpose of checking the level of the soil and smoothing it out. The verge should be made about 3 in. wider than it will be finally; this makes seeding or sodding easier and when established the edge can be cut back to the width required. Wide verges are preferable to narrow.

In turfing a verge the sods should be laid carefully and truly and then lightly beaten and rolled. When the verge is well established and after the edges have been cut to the decided width, it is sometimes advisable to support the edges with steel strips. If the border and path are on a sloping grade the verge should follow the gradient also.

The production of banks on lawns and sports grounds is a matter that requires careful consideration and planning. Where the scheme is one of formal arrangement, then it is necessary

to secure the levels very carefully because the effect will be lost if there is a wavy margin to the bank. In less formal work the general level and arrangement should be decided, after which some undulations and irregularities are allowable. The upper and lower edges of the bank should first be determined by pegs and horizontal straight-edges, and the slope should then be checked by means of a further straight-edge placed up the slope which can also be used to regulate the depth of the soil. In deciding upon the angle of the slope consideration must be given to the fact that the bank will eventually require mowing; generally speaking an angle of 30 to 35 degrees is satisfactory. Not only does this help to conserve moisture and prevent excessive baking in drought, but the general effect is more pleasing. The slope should be so graded that the upper edge is gently rounded to avoid skinning by the mower and the basal part should be tapered out in a gentle curve so as to permit uniform cutting at the foot.

In preparing the bank a good depth of soil is required, and this soil should be well dug, working sideways along the bank and turned up-hill before chopping the clods down with the spade. If necessary, amelioration of the soil may be carried out as advised under the general construction of lawns. All general work and cultivation of the surface should be done in an uphill direction to minimize the tendency for the soil to roll down to the lower levels. Many banks suffer from a deficiency of soil on the upper edges and an excess at the base of the bank. Consolidation of the bank is rather important, so as to reduce erosion and to conserve moisture, and after testing the angle with a straight-edge, trampling and beating of the soil are required.

When banks are sown there is always some danger of the seed being washed away by heavy rainfall, and it is not uncommon to find that the upper edges are deficient, having too few seedlings, whilst the base of the bank is overcrowded. Seeding of banks is perhaps best carried out in the late summer because the grass can get well established before the winter, thus being in a better position to withstand drought the following season. The washing away of seeds on banks may be minimized by the device of placing horizontal laths at intervals along the slope, these being later removed when the young grass is well up. Although bare strips are left by this process they readily fill in

and are soon lost. Another method is to cover temporarily with cheese cloth.

In turfing banks the sods should be laid from the base of the slope upwards, the size of turf depending upon its nature. Large turves are more difficult to handle so that 1 ft. by 1 ft. and 1 ft. by 2 ft. are usual. The work should be done in an uphill direction, the turf being gently beaten, the operator standing at the top or part way up the bank. The beater should consist of a piece of thick board to which a handle has been attached at an angle.

In constructional work, when an artificial mound has been produced on the flat and where the turf has been rolled back for the purpose, it is comparatively easy to unroll the long strips, which may be from 6 to 10 yd. in length, and put them into position quickly. As when turfing on the flat, the turf banks should be dressed with sand or sandy loam and compost, to facilitate knitting and establishment of the turf.

Chapter Twelve

The Vegetative Production of Turf

he vegetative method of producing turf has received very little practical attention in this country, but is worthy of consideration because of the comparative ease with which uniform turf can be produced. It may, therefore, be of interest, especially to those of an experimental turn of mind, to try out the method. Usually, vegetative turf production is done with creeping grasses but it can be carried out quite easily with non-creeping species, using their shoots or tillers and dibbing them in at intervals of 2 to 3 in. These shoots rapidly tiller-out to form thick plants, and with top-dressing soon make a turf. Another way is to obtain some sods of, say, *Agrostis tenuis*, and to tear or shred them up into separate shoots and scatter these on the prepared surface. After light top-dressing roots are made and tillers produced, and then by occasional mowing and top-dressing a continuous sward soon develops. Thus a square-foot sod of *A. tenuis* made 40 to 50 sq. ft. of excellent uniform turf. Practical examples of the vegetative method of turf production exist on the St. George's Hill and Wentworth Golf courses, Surrey, perhaps the only large-scale examples in the country. Some years ago a number of new greens were prepared in this way, rough turves and stolons of a slightly rhizomatous *Agrostis* being broken up and scattered on the prepared soil, and gradually worked down into an excellent sward.

Vegetative turf production is usually carried out with species of grass which form extensive surface runners or stolons. In this country Creeping Bent (*A. stolonifera* var. *compacta* Hartm.) and Velvet Bent (*A. canina* L.) have been used experimentally.[19]

[19] *Jour. Bd. Green. Res.*, 1930, I, No. 2, 71.

Although it is rather more cumbersome than the production of turf from seeds, the method is so simple and can so easily be carried out in practice that it is astonishing that no nurseryman has seriously taken up the growing of stolons on a large scale in this country (see Fig. 7).

The method involves three separate operations: (1) growing a crop of stolons, (2) planting out these stolons, and (3) working them down, when established, into a turf. The two species of *Agrostis* referred to above form extensive runners in August and September, and in the first-mentioned species they may be from 24 to 30 in. long, or in the second species from 12 to 18 in. Both species are very variable, but the forms with which experiments have been done are leafy types that are vigorous and produce a dense, fine turf. They are shy seeders and the best way of producing a crop of stolons is to plant in spring separate shoots of the selected grass or 1-in.-square pieces of turf, about 2 ft. apart in each direction, and assuming the soil is reasonably fertile a vigorous production of stolons results. One square foot of turf broken up and planted out will grow a crop of stolons sufficient for planting several thousand square feet of prepared soil. At the end of August or beginning of September these runners are pulled off the parent plant, chopped into short lengths about 2 in. long and scattered lightly like chaff on the prepared soil bed. The speed of turf formation depends largely upon the number of short lengths of stolon scattered upon the prepared ground. Spacing can be increased or decreased according to the amount of material available, but one or two pounds of stolons is enough for 10 sq. ft. of lawn, or 1 sq. ft. of stolons of creeping bent is enough for 10 sq. ft. A very light covering of soil is then necessary followed by light rolling with a wooden roller, after which roots and shoots develop at the nodes, followed by tillering out of these young plants. It is, of course, important in dry weather to keep up the supply of moisture. As soon as the shoots are established, gradual working down can commence.

Another way of planting is to take the complete stolon and plant in rows from 4 to 6 in. apart.

Turf of both the above grasses put down in September, 1930, was in excellent condition by June, 1931, and could have been used as a putting green. The turf of both species is fine in leaf, dense and remarkably uniform throughout, and is still in the

same excellent condition after ten years. One advantage over seeding is the greater uniformity that can be obtained, because, given time, thousands of square feet of turf can be produced from the division and sub-division of a single selected plant (see Fig. 9).

For the sake of completeness and for the help of readers abroad information is included below upon vegetative turf production in other countries with other species of grass.

In the United States the production of golf greens and lawns by the vegetative method is common, and many golf clubs maintain nurseries in which they grow supplies of recognized varieties of bent for turf production. In this country various clubs and private individuals have started nurseries of this type from material supplied by St. Ives. One golf club produced 1,200 sq. yd. of *A. canina* turf in this manner.

Unfortunately some of the American varieties of creeping bent have earned ill repute because of their tendency to form a nap or grain, which makes putting on golf greens uncertain, as the speed depends upon whether the ball runs along or against the nap. The strains of creeping bent and velvet bent with which the experiments referred to were carried out, do not show the same tendency to nap as the American creeping bents. They are more leafy and finer in texture but require careful top dressing and planting in suitable soil. Much selection work is now being done with velvet bent in the United States. In the comparative quality trials of North and Odland [20] three strains of velvet bent were rated first at 89, 88, and 86 per cent respectively, against New Zealand browntop 83, Metropolitan creeping bent 71, Washington creeping bent 67 and Virginia creeping bent 46 per cent. The rating was based upon observation of vigour, colour, texture, density, disease resistance, and general quality.

In the southern States of North America, i.e. approximately south of latitude 38°, it is unwise to risk planting bent, but in these warmer southern States a variety of grasses may be used for vegetative production of turf. Thus suitable species propagated vegetatively in Florida, as described by Enlow and Stokes [21] are Bermuda Grass (*Cynodon dactylon* L.), St. Augustine

[20] North, H. F. A. and Odland, T. E.: Bull. No. 245, Rhode Island Expt. Station, 1934.

[21] Enlow, C. R. and Stokes, W. E.: Bull. No. 209, Florida Expt. Station, 1929.

Grass (*Stenotaphrum secundatum* Walt.), Carpet Grass (*Axonopus compressus* (Siv.) Beauv.), Centipede Grass (*Eremochloa ophiuroides* (Munro) Hack.), and St. Lucie Grass, a non-rhizomatous variety of Bermuda. In the southern part of Kansas [22] Bermuda grass is used for lawns, whilst in the west Buffalo Grass (*Bulbilis dactyloides*) propagated vegetatively resists extremes of temperature and drought.

The *Cynodons* are cosmopolitan, and varieties and species are also extensively used for vegetative turf production in other countries, the names adopted being: Bermuda in U.S.A., Kweek in South Africa, Neguil in Egypt, Dhoob or Doob in India, Serangoon in Malay (see Fig. 8). Kikuyu (*Pennisetum clandestinum*) and Durban Grass (*Dactyloctenium ægyptium*) are both used vegetatively in South Africa.

Tropical grasses have been introduced into the southern States of North America, and species like *Zoysia* [23] (Korean or Japanese lawn grass), and Blue Couch (*Digitaria didactyla*) from Australia, are propagated vegetatively. Other species of *Zoysia*, like *Z. tenuifolia* (Mascarene grass) which forms a fescue-like sward, are being tried out along the Gulf Coast.[24]

In the hotter parts of Australia Bermuda grass and blue couch are extensively propagated by stolons, and these species, as well as others like *Zoysia* and species of carpet grass and *Paspalum*, are used for producing lawns and for the various parts of golf courses in Malay.[25]

While it is granted that the production of turf by vegetative means is easier in tropical than temperate climates, nevertheless the method has been so successfully adopted in the semi-temperate parts of the United States that there appears to be room for considerably more attention to the subject of turf-making by stolons in this country.

Finally, brief mention may be made of the production of a sward with a non-gramineous plant—Camomile (*Anthemis nobilis*). It occurs as almost a pure stand in large patches in some of the royal parks. Propagation may be carried out by splitting a turf and planting the shoots one or two inches apart, when it will form a sward.[26]

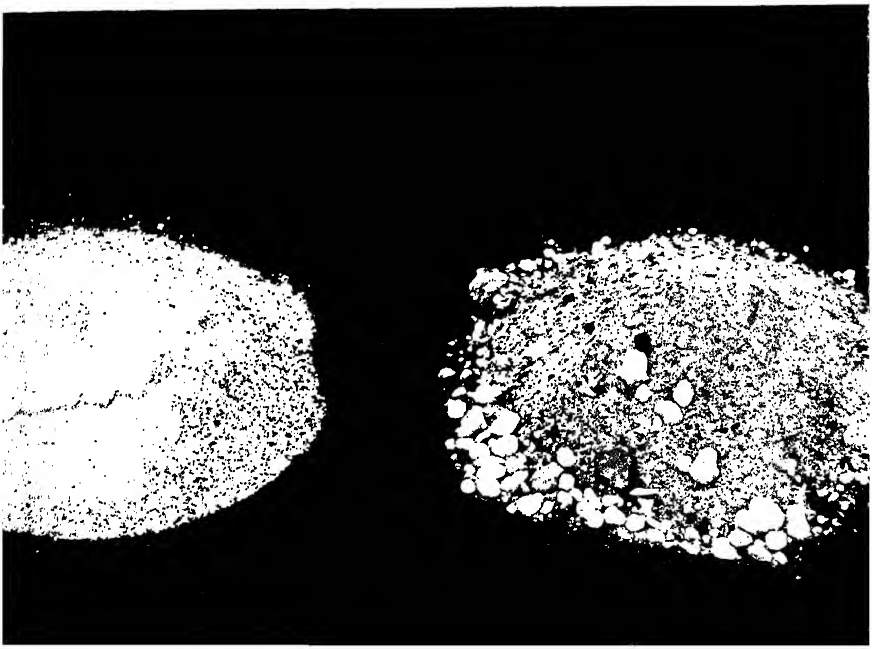
[22] Zahnley, J. W. and Quinlan, L. R.: Bull. No. 267, Kansas Coll. of Agric., 1934.
[23] Bull. U.S. Green Section, X, No. 10, 178.
[24] Piper, C. V. and Oakley, R. A.: *Turf for Golf Courses*, 1929.
[25] Lambourne, J.: *Malayan Agric. Jour.*, 1937, XXV, Pt. 1, 3.
[26] *Jour. Bd. Green. Res.*, 1936, IV, No. 14, 185.

SECTION III

MAINTENANCE OF ESTABLISHED TURF

Fig. 12 (*above*).—The compost heap, showing layers of soil and manure, and a rotary screen.

Fig. 13 (*below*).—Fertilizer mixture. *Left:* in good mechanical condition. *Right:* bad mechanical condition.




A III 17 4
B II 12 7
C I 1
D I 26
A IV 27 6
B I 64
C II 15 1
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Chapter Thirteen

Grass Mowing and its Effects

Most lawns are mown in a haphazard manner but if the best results are to be obtained it is essential that mowing be carried out systematically and with circumspection. There is something more in mowing than just keeping the place tidy or disposing of the leafage produced; mowing must be controlled in accordance with the purpose for which the turf is intended, and frequency and intensity have an influence on turf density, weed infestation, earthworm activity, and yield of clippings. The return or removal of the cuttings also affects the equilibrium of the plant population composing the sward.

Nearly all lawn and sports turf is mown nowadays with some type of rotary mower—a machine that has introduced a new and potent factor into modern lawn maintenance. No doubt the rotary mower has made fine lawns possible, but the effects are different from those brought about by scything and grazing, the older methods of keeping down growth. Under the influence of the rotary mower the grasses are perpetually "over-pruned" and nothing is returned to the soil as in grazing. As a result the flat rosette weeds (e.g. dandelion, cat's-ear, daisy, etc.), the mat weeds (like yarrow, pearlwort and selfheal), and the clovers spread below the cutting blade and by their crowding smother and reduce the tillering capacity of the grasses. If the sward is "let up" to the scythe or the grazing of stock the competition against these bottom growing plants is much greater. Further, in a mixed sward containing finer grasses, rye-grass and clovers, the fine grasses (bent and fescue) are less palatable than the rye-grass and clover and so suffer much less defoliation. Under grazing these fine grasses are at an advantage as compared

with rotary mowing, whilst under the scythe the difficulty of cutting them also acts in their favour.

It is a common complaint that seaside golf greens, for example, are no longer composed of fescue, and mowing is undoubtedly an important, though not the only, factor involved in their decline. The greens on some of the old-established links were at one time kept short by occasional scything but mainly by rabbit nibbling. Rabbits are remarkably selective in their grazing, choosing the softer leaved and lusher grasses like rye-grass and the meadow-grasses, as well as the clovers, whilst leaving the fescues relatively unharmed. In some Wiltshire experiments Thomas [27] has shown that the effect of enclosing rabbits on an area of pasture reduced the agriculturally useful grasses (*useless* for fine turf) from 32 to 7 per cent in 15 months. They reduced the clover from 51 to 4 per cent. The moss and weeds increased, it is true, but grasses such as bent and fescue, the agriculturally useless grasses (*useful* for fine turf) remained almost unaffected and actually showed a 3 per cent increase.

The transition of meadow and pasture to a fine turf may be seen on many golf courses, the rough containing taller growing hay species, the fairways approximating to a well-grazed pasture, whilst the greens contain in the main turf grasses like bent, fescue and annual meadow-grass. The change from pasture to lawn has been critically studied by Harrison and Hunt [28] who found that regular mowing and dressing of a section of pasture to form a lawn led to a reduction of rye-grass and clover combined from 75 per cent in the pasture to 6 per cent in the lawn, and an increase in bent from 14 to 83 per cent, which provided a very uniform surface.

The effects of mowing fine lawns may be studied experimentally from at least two angles—the intensity of the cutting and the frequency—and as these two aspects have been studied separately and in combination at St. Ives during the last few years, some references to the results may be included at this point.

Intensity. A sward sown with New Zealand browntop in 1931 was divided into two strips each 100 sq. yd. in area, and whilst the frequency of mowing each was the same, the intensities

[27] Thomas, J. O.: *Farmer and Stockbreeder*, Aug. 10, 1937, p. 1937.
[28] Harrison, R. M. and Hunt, I. V.: *Jour. S.E. Agric. Coll.*, 1937, **40**, 148.

were different, namely, $\frac{1}{8}$ in. and $\frac{3}{8}$ in. height. The cuttings were removed and weighed on a dry-matter basis, observations being made on various other points. Dealing firstly with the yield, and calculating that on the short-mown plot as 100, then the relative yield from the long-mown plot lay between 75 and 97, according to season, as in the table below:

Year	1932	1933	1934	1935
Duration of cutting season in weeks	20		27	39
Short cut, $\frac{1}{8}$ in.	100	100	100	100
Long cut, $\frac{3}{8}$ in.	75	96	97	87

The longer-mown turf has therefore yielded consistently less grass clippings. Botanical analyses in 1934, after the experiments had been in progress two full seasons, showed the presence of 17·6 per cent of annual meadow-grass and 6·3 per cent of weeds on the long cut, whilst under the short cut the respective figures were only 0·5 per cent and 2·1 per cent—showing that keen mowing is controlling weeds and annual meadow-grass. On the other hand, moss was more common on keenly-mown plots than on long. Counts of shoots or tillers made on each strip showed that close cutting, irrespective of other treatment, gave a denser turf than long cutting, in the proportion of 100 shoots on the short to 56 on the long. As an example of the density of the turf on the short-cut plots the area receiving sulphate of ammonia had 53 shoots per sq. in. as against 39 under the same manurial treatment but mown long. Observations on cast formation by earthworms, which may be taken as an indication of earthworm activity, have shown approximately three times as many on the long cuts as compared with short cuts. The explanation of this may lie in the heavier withdrawal of plant nutrients and soil bases on the more intensively mown area, leading to a soil medium less suitable to earthworm activity.

Frequency. Two swards made respectively from New Zealand bent and Chewing's fescue were subjected to a system of weekly and thrice-weekly mowing for a period of 24 weeks. They were cut to the same intensity and were treated in all other respects in an identical manner. The weekly produce from each plot

was weighed on a dry-matter basis and pooled in four-weekly lots. The data [29] showed that under both systems of cutting and on the average for the season the fescue yielded 10 per cent more clippings than the bent. Moreover in the early part of the season the fescue yielded almost twice as much herbage as the bent.

It has been shown by grassland workers that the yield of leafage is inversely related to persistency, and the result of this experiment suggests that Chewing's fescue may not be as persistent as bent. This is found to be true in practice. Further, the fact that the yield of fescue is so much heavier in spring also leads to the supposition that the persistency of this grass is being undermined, it being known that species that produce heavy yields in spring are adversely affected if defoliated at that time.

A comparison of the yields under the two frequencies of mowing shows that both swards yielded consistently less total produce when mown thrice weekly than when mown once weekly. There was also a correspondingly reduced withdrawal of nutrients from the soil where the three cuts were given, and of course a more suitable sward resulted. Increasing the cuts to say six per week would no doubt show a further reduction of total yield and in fact mowing of intensively managed turf is rapidly becoming almost a daily operation.

Frequent and intense defoliation has the effect of leading in time to deterioration of the turf, but this can hardly be due to the withdrawal of the plant foods since analysis of the produce shows that less is removed under frequent mowing than less frequent. More probably it is due to the direct weakening effect on the plant, the root ranges being shortened and so placing the grass at a disadvantage. Thus in a bent sward the root weight was reduced from 100 to 86 by trebling the frequency of mowing. The decrease in yield of top growth and roots (a common finding in practice) is not easily accounted for, but is probably due to a reduced assimilating power and to the reduced carbohydrate reserves of the plant being a limiting factor under intensive defoliation.

Intensity and Frequency Combined. In a third experiment both factors, intensity and frequency, have been studied in

[29] A fuller account of this experiment appears in *Jour. Bd. Green. Res.*, 1932, II, No. 6, 196.

combination on a series of 64 plots during a [illegible] season of 29 weeks in 1937. The table below shows the relative yields of grass clippings on a dry matter basis:

Height of cut	*Mown once a week*	*Mown thrice a week*
$\frac{1}{8}$ in.	100·0	88·8
$\frac{3}{8}$ in.	92·4	75·3

Weekly mowing, irrespective of height, produced greater yields of clippings than thrice-weekly mowing. Keen mowing irrespective of frequency, yielded more clippings than longer mowing. Most clippings were removed from the areas mown short at less frequent intervals, whilst least clippings came from the area mown frequently at the longer height. Thus from the point of view of the grass plant it received most defoliation, perhaps mutilation, when mown keenly at low frequency, whilst least permanent damage was done to the plant when cut less keenly at three times the frequency.

Practical Considerations. The practical interpretation of the results of these experiments is that mowing should be done regularly but not too keenly. Unfortunately many lawn owners do just the reverse, they cut their turf weekly or fortnightly and to ensure as long an interval as possible before it needs attention again, they mow as keenly as their machines will let them. Nothing could be more damaging to a sward than such a spasmodic system of mowing, and no doubt this maltreatment often accounts for the thin swards, open to weed invasion, which are all too frequently to be found. It may be argued, especially on large lawns, that more frequent mowing is impossible, as time does not permit, but this difficulty may largely be surmounted by modern methods of mechanization, which, instead of releasing labour for other work, should be used to enable the turf to be cut more often without any greater expenditure of time. Advertisements for machines designed to speed up mowing often stress the increased leisure or time that will be gained for other work, but such enticements do a disservice to the lawn since time saved should be used profitably in mowing two or three times as often with the blade of the machine slightly raised.

Mowing should therefore be controlled and should be given careful thought, taking into consideration all the relevant facts. The degree of frequency must in practice be largely governed

by the amount of growth, which is in turn related to the weather conditions, season of the year, and fertility of the soil. For example, the time taken to mow a certain playing field varied from 8 to 9½, 12, 13, 17, and 20 hours.

All practical men know they can make a nicer job at mowing when the grass is dry, and they know further that wet mowing is a longer process owing to the need to stop more frequently to clean the machine and to heavier "going". A timing test showed that a job that took 45 minutes in dry weather required 60 minutes in wet.

Ribbing of the grass by the mower blades is a point of importance. If the turf is ribbed it is a sign that the cutting has been too long delayed or the cutters set too tight or that the revolutions of the cutting cylinder are too few—in other words the machine is incapable of doing better.

It is a mistake to allow the grass on a fine lawn to become long in winter; it should be topped in open weather—but not cut keenly to summer level—when thought necessary. Many lawn owners allow their turf to grow 3 or 4 in. long in spring before mowing, a process both damaging to the grass and apt to open up the sward. In dry weather in summer the blade should be raised. Cutting should, if possible, be avoided during cold east winds, or discoloration of the leaf tips is likely to result.

The problem of deciding whether to allow the clippings to return to the turf or whether to remove them in the box is one that often causes trouble to the amateur. It must be said at once that there is no hard and fast rule, but during a drought the cuttings should be returned to act as a mulch, while if the turf is cut when wet the mowings should be removed, as otherwise they cling together in unsightly patches. An experimental area was divided into two strips; on one the cuttings were always removed and on the other they were always allowed to return irrespective of weather conditions. After several seasons some striking differences emerged and these have a bearing upon the mowing of large areas like golf fairways where the mowings are always allowed to fly, the gang-mowers having no boxes. In the experimental plots there are regularly more worm casts on the plots to which the cuttings are returned—possibly a reflection of the greater amount of organic matter which this strip is receiving. This sward also contains more annual meadow-grass (*Poa annua*) to the extent of 26·0 per cent of the herbage as

against 6·0 per cent when the cuttings were removed. Boxing the clippings therefore helps to control this species. Further, the turf to which the cuttings are returned is consistently softer, spongier, and lusher than the other turf, though in dry weather it is moister and more drought resistant. On the other hand, the turf to which the clippings are returned is greener in winter and there is no moss invasion as compared with the other strip, where moss is prevalent. These differences were brought about by *regular* return or removal of the cuttings, but they indicate the trend.

The return of the grass mowings to the turf conserves plant food, since mineral matters present are replaced by decomposition of the clippings, but against that the requisite plant foods may be easily and cheaply applied in the form of artificial fertilizers.

Cutting of the lawn should always be done neatly and in parallel strips but the direction of these should differ at each cut, following the points of the compass, because this leads to a better control of strong shoots of rye-grass or runners that tend to form on the surface. The control of plants like rye-grass may be facilitated by regular brushing or drag matting, and every lawn should be switched to remove sticks, pebbles; worm casts, or other débris before putting the machine over.

Sometimes lawns and sports fields regularly cut with motor or gang mowers develop a series of wave-like ridges, sometimes quite pronounced, about 8 to 12 inches apart and at right angles to the direction of mowing. In minor cases the grass only is affected, but in serious cases there is ridging of the soil itself. This "corrugated" or "washboard" effect is most pronounced in wet weather, being rarely seen in dry and is probably associated with rhythmic movements set up in the motor unit. It may be remedied by a change in the direction of mowing (diagonal or at right angles) and by cross rolling.

Mowing is not the simple operation of removing excess growth, as many imagine, but a process having far-reaching effects and therefore worthy of the most careful study and control.

Chapter Fourteen

The Choice of a Mower

here is to-day an extraordinary range of lawn mowers for all purposes and pockets and the main considerations in purchasing a new machine are (1) the money available, and (2) the size and nature of the area to be cut. Among the hand machines there are two main types, (*a*) roller machines in which the cutters are driven by gearing or chain from land rolls, and (*b*) side-wheel machines in which the cutting cylinder is driven from the wheels. Each machine may be had in several widths and with a choice of blade number. The number of blades and the speed at which they revolve determine the frequency of cuts to the yard. The finer the lawn the higher must be the number of revolutions to avoid ribbing, and it will generally be found that low-priced machines do not give the number of cuts to the yard that are given by the higher-geared and thus more expensive machines.

The average "garden mower" is designed to be a general purposes machine capable of dealing with long and short grass and hence the number of cuts per yard is usually 50 to 60. With lower-priced machines rougher conditions are allowed for and the number of cuts is reduced to 40 to 50 per yd. The above refers to roller-driven machines, but the principle is equally applicable to side-wheel machines. Further, in the dearer machines the wheel-base is less and the cutting cylinder nearer to the front roller, so reducing skinning on uneven or undulating turf (see Fig. 10).

Inexpensive side-wheel machines with four blades may be obtained at as low a price as 22*s*. 6*d*. to 30*s*., but they will not give the fine finish of a more expensive machine. Intermediate-priced ball-bearing machines of the side-wheel type for

small lawns may be had for as little as 37*s.* 6*d.* or 40*s.*, and of the roller type from £2 15*s.* to £7 10*s.*; the latter machines not only put a better "finish" on the surface but they rib less and also enable mowing to be done up to the edge of verges. From £12 to £16 must be paid for a high-speed non-ribbing roller machine (100 cuts per yd.) suitable for the finest lawns or golf greens. To facilitate mowing banks small side-wheel machines fitted with a long handle may be obtained.

The mechanization of lawn mowers has been one of the most striking developments of recent years and a wide range of power machines is available. Two types of motor machine may be considered, first those in which engine power is used for obtaining forward motion as well as for driving the cutting cylinder, and, secondly, those in which the cutting cylinder only is driven, the machine being pushed by hand. In the former class there is a wide range of makes and sizes for all conditions, and the figures below show some of the widths and types of machines with their capacity in acres per day and the area of turf for which they are best suited.

Table Showing the Capacity of Various Types of Mower

Size and Engine Type	Capacity, Acres per Day	Suitable for areas:
14-in. 2-stroke .	2 acres	up to 1 acre
16 " 4-stroke .	$2\frac{1}{4}$–$2\frac{3}{4}$	up to 2 acres
20 " 4-stroke .	3–$3\frac{1}{2}$	up to 3 or 4
24 " 4-stroke .		up to 4 or 5
30 " Air-cooled .	4–$4\frac{1}{2}$	up to 5 or 6
36 " Water-cooled	10	up to 6 or 10
42 " Water-cooled	12	up to 7 or 12

In some of the latest patterns of motor machine the land roller and cutting cylinder are engaged by separate dog clutches. The machine may thus be used as a roller or hand propelled with the cutting cylinder only in operation. Some models are fitted with a fluid clutch so that on opening the throttle the machine glides forward. Improvements in lubrication are also a feature.

A comparison of two makes of motor lawn mower, one costing below £20 and the other over £30, showed that with the former only 42 cuts per yd. were obtained whilst in the other the num-

ber was 73 cuts. Frequency of cut is therefore a matter requiring attention when purchasing (see Fig. 11).

Much of the energy expended in pushing a hand machine is absorbed in driving the cutting mechanism at the necessary speed. In mowing machines in which the cutting cylinder only is driven by the engine (forward movement being by hand pushing) as many as 1,200 r.p.m. can be obtained, and this leads to more uniform mowing. In this principle the lightness of a hand machine is retained but energy is only required for giving forward motion. The claim is made that the increased speed attained involves a saving of 15 to 20 minutes per hour. Ribbing is eliminated. Some of the electrically driven machines are built on this plan.

In recent years there has appeared another type of machine in which three fan-like blades revolve in the horizontal plane. The working speed is 6,000 cuts per minute and the cutting is done by small steel discs on the corner of each blade which "flick off" the long grass rather than "cut" through it; there is no bottom blade. The machine will mow long grass, is light to use, and will cut close up to fence and wall bottoms.

Further refinements in the direction of speeding up mowing have been in the direction of using a small $3\frac{1}{2}$-h.p. engine carried on a two-wheeled balanced chassis, guided by one man and dragging three roller-type mowers, thus giving a cutting width of about 45 in.—in other words, doing three men's work with a combined outfit. With this implement half an acre can be mown to putting-green condition in 45 minutes.

For large areas the horse mower is gradually becoming a thing of the past and mowing is now usually done by tractor. The table below shows the acreage possible with horse-drawn machines in comparison with modern multiple-unit mowers drawn by tractor.

For long grass mowing there are various machines, some on the rotary system capable of mowing long grass at a rapid speed, and others with a cutter bar fitted at one side or directly in front and able to mow 8 to 12 times as fast as scything and to deal with 4 to 5 acres per working day.

Having chosen a sound machine to suit the particular purpose it is desirable that it should be kept in worthy condition. Small faults often lead to further damage and perhaps a breakdown. The first cut of the season is best taken high in case any debris

Table Showing the Capacity of Horse- and Tractor-Drawn Mowers

Size and Type of Machine	Capaci	Suitable for
Pony mower, 30-in. . . .	acres	Park turf and small sports grounds
Horse mower, 42-in. . . .	3½–4 ,,	
Triple mower (horse drawn), 84-in.	12–14 ,,	9-hole golf courses and sports grounds
Triple mower (tractor drawn), 84-in.	20 ,,	Golf courses, sports grounds, and playing fields
Tractor drawn Quintuple, 11 ft. 6 in.	35–40 ,,	
Tractor drawn Septuple, 16-ft.	50–60	Large playing fields and aerodromes

has been overlooked. The mower should not be bumped over kerbs or steps as this may knock up the bottom blade against the cutters or result in a broken casting. Tight setting of the fixed blade on to the cutters, or over low cutting, will lead to excessive wear. When mowing the handles should be gripped firmly to ensure a firm downward thrust through the land roll or side wheels—depressing the handle of a roller mower may lighten labour but the resultant finish is bad.

A steady walking pace, cultivating the knack of merely steering, is ideal for motor mowers, and they should not be flogged by mowing beyond their capacity. Where the grass is long overloading can be avoided by topping it first. The driving chains should be correctly adjusted, and when letting in the clutch the load on the transmission can be eased by momentarily depressing the handles. Hauling gang mowers at excessive speed is a common cause of premature depreciation. On motor scythes adjustment of fingers to the cutter bar is important. All mowers require systematic and regular oiling of all bearings and working parts.

After use mowers should be brushed or washed down then dried and wiped over with an oily rag. Regular cleaning affords an opportunity to examine for loose or lost nuts. About mid-season heavily used mowers will benefit by light grinding in, but most owners of small lawns only require to have this done for them during the winter months by the makers or their agents.

Appendix 3, p. 296, deals with storage and adjustments.

Chapter Fifteen

The Preparation and Use of Top-Dressings

op-dressing of intensively-managed turf is almost as essential as mowing, and should form one of the regular operations of maintenance. Top-dressing refers to applications of materials low in manurial value but having considerable bulk, and not regarded as fertilizers. The general purpose of top-dressing is either to improve the surface of the turf or to develop a mat giving some degree of resiliency. An improved surface means more uniform mowing and results too in a "fining down" of the grass. Top-dressings are also valuable as a vehicle for spreading relatively small amounts of concentrated fertilizers, and they may be used for introducing organic matter and ameliorating the condition of the soil.

The top-dressing of golf and bowling greens is a well-established practice. Examination of old-established greens often shows layer upon layer built up of annual dressings of sand and compost going back over a long period. It is just as important that some top-dressing should be carried out on lawns.

Perhaps the commonest and most useful form of top-dressing for use in lawn and green upkeep is compost, which term has rather a wide range of application. Usually it refers to a mixture of soil and decayed vegetation or decomposed farmyard manure. The best soil to use for such a mixture is a friable loam containing 10 to 15 per cent of clay and not more than 20 per cent of coarse sand. Such soil is friable, crumbles well and mixes easily with other materials. It is often found that in preparing compost the soil ingredient has been either entirely or largely omitted; but on the contrary the inclusion of some soil in a mixture is as important as including a suitable form of organic matter. The use of organic matter alone in the form of leaf

mould or fresh manure often leads to ill results in the form of a spongy surface, tendency to water-logging and disease. It is appreciated that the making of compost to include soil may be difficult for the small lawn owner, and also that there may be the danger of introducing weed seeds. This can be got over by exercising some foresight and spreading out the soil to be used in a shallow layer and allowing weed seeds to germinate—although many of the weed seeds found in garden soil are from plants that do not establish in turf, e.g. chickweed, shepherd's purse and mayweeds.

Various forms of organic matter may be used in preparing a compost, such as farmyard manure, old turf, leaf mould, grass cuttings, sheep's droppings and even malt culms. Grass cuttings and manure may both be a source of weed seeds, which may, however, largely be destroyed if the heat of fermentation is sufficient.

Finished compost does not depend for its value upon its fertilizing ingredients, since it rarely contains more than 1 per cent of nitrogen and even less phosphoric acid and potash, but whilst the percentage of these materials is low it should be realized that the rate of application of the material may be heavy. Compost is of primary importance on account of its physical properties, though there is evidence to show that root development is favoured by its use. It also helps to conserve moisture by acting as a surface mulch.

In practice a good compost heap is best built up with alternate layers of soil (9 in. deep) and organic matter (3 to 4 in. deep), the heap being allowed to stand for a period of about 12 to 18 months to ensure good decomposition. The material is then cut down and screened. Sharp sand may then be added. For most purposes a $\frac{3}{16}$-in. mesh is adequate, but for finer turf a $\frac{1}{8}$-in. mesh should be used, and when large quantities have to be handled a rotary screen is essential. It is advisable to test the material for weed seeds by placing some in a box and keeping it moist and warm (see Fig. 12).

If dung is used as the source of organic matter it is important to realize its variability, due to the type of food fed to the animals, the kind of animal, the age of the dung, the storage, and the nature of the litter. Horse manure on peat moss-bedding is generally accepted as the best for this purpose, since more of the liquid excrement is retained in the peat and

there is less likelihood of weed impurities than with straw litter.

By decomposing waste vegetation with the assistance of a chemical accelerator such as "Adco" excellent supplies of rotted organic matter equivalent to farmyard manure can be produced ready either for including in compost heaps or, after more prolonged decay, for direct application to turf.

Compost heaps and prepared material should always be protected from the elements. A heap exposed to rain loses nitrogen, while screening is made difficult if the material is saturated with moisture. It is a good plan for a new heap to be in course of construction at the time the old one is being brought into use so that a continuous supply is available.

All the dangers and anxieties of using soil and manure containing weed seeds in compost piles can readily be overcome by the process of sterilization by heat. There are three main methods by which this may be carried out, namely by baking, by steaming, and by electricity. The baking process is usually carried out in a shallow brick trough below which run flues from a furnace situated at one end. The heat thrown up under the base of the trough raises the temperature of the material. A suitable type of baking plant is the "Reaseheath" pattern, but experience has shown that the trough is too long if heating throughout is to be satisfactory without charring at the furnace end. The plant can be much improved by shortening the length and increasing the width in what is termed the "Wilmslow" plant, or the same length may be used by introducing a false bottom with wider air space over the furnace, in what is called the "Enthoven" plant. These sterilizers hold approximately 3 tons and the cost of heating with coke as fuel is about 1*s*. 6*d*. per ton. Turning of the material is advisable to ensure that the material at first on the surface becomes adequately heated. There is also the "Holmes" or vertical type of baking plant, but loading of this is more difficult.

For steam sterilizing a vertical boiler and a grid of perforated steam pipes is required. The grid is placed in a shallow pit and compost to a depth of about 20 in. placed over it. The capacity is about 1 ton and steam at 40 to 60 lb. pressure is passed through. The temperature is quickly raised and by this means 1 ton may be sterilized in approximately half an hour. Baking requires longer. Small portable low-pressure steaming plants may

be obtained for garden use, and take from one to several cwt. of material.

In the third method a current of electricity is passed through the material, the resistance of which raises the temperature. The consumption is from 1 to 1⅓ units per cu. ft., depending upon the nature of the soil. Sterilizers of various capacities are made, from small ones (30 to 40 lb. and 1-cwt. sizes), useful for the amateur gardener, to larger outfits holding ⅓, ½ or 1 ton of compost. The process is complete in 60 to 75 minutes.

It is often said by those concerned with the preparation of compost that sterilization destroys some of the properties of the material. The effect is to destroy fungal spores, some bacteria, earthworms, weed seeds, and insect pests, and it has been shown that this is complete at a temperature of 160° F. if it is maintained for 30 minutes. On the other hand, it has been shown that nitrifying and other bacteria are not destroyed at this temperature, so that the material benefits from the process, which is in effect pasteurization. In practice it has become usual to raise the temperature up to about 212° F. Fig. 14 shows the benefit to grass plants when grown in sterilized soil.*

Recent work by Monteith in the United States (*Turf Culture*, 1939, I, No. 1, 63) has shown that compost heaps can be successfully treated with the tear gas chloropicrin (trichloro-nitro-methane) for the destruction of weed seeds. The pile was built in 6-in. layers each receiving a portion of the liquid on the basis of 30 oz. by weight per cu. yd. After sealing the heap with kraft paper for four days it was found that 100 per cent of the seeds of *Poa annua* and chickweed were killed and 15 per cent of clover. Seed beds containing dormant weed seeds have also been treated successfully by injecting the poison into the soil. Over 90 per cent of all weed seeds were destroyed. No toxic effects remained after a week or ten days.

Experiments by Lawrence and Newell [30] on the preparation of composts for potting purposes have shown that lime or chalk should not be added before sterilizing. Storing of compost for a period before use is always recommended, but these workers

* Further accounts of compost preparation and use may be found in *Jour. Bd. Green. Res.*, I, No. 3, and II, No. 7, whilst sterilizing plants are described in detail in *Jour. Bd. Green. Res.*, I, No. 3, and III, No. 9, and V, No. 18.

[30] Lawrence, W. J. C. and Newell, J.: *Seed and Potting Composts*, 2nd ed., 1941.

have shown that the check to growth associated with newly-sterilized materials can be avoided by addition of superphosphate afterwards. They recommend that the ingredients (e.g. sand and loam) should be separately sterilized, followed by addition of such materials as granulated peat and fertilizers. The effects of preparing composts in various ways were studied on a variety of plant seedlings but not upon grasses. It is, however, the usual practice in greenkeeping and lawn management to add the fertilizers for the turf to the composts after sterilizing. There is therefore no necessity to remedy deficiencies in the compost.

The amount of compost to use will depend upon conditions. On a very uneven surface as much as 2 tons to 1,000 sq. yd., repeated on several occasions, is needed, whilst for spring and autumn dressings of compost the rates may be up to 2 lb. per sq. yd., i.e. nearly 1 ton per 1,000 sq. yd. Rates of 4 to 8 oz. per sq. yd. are adequate as a medium for the spread of artificials.

The distribution of compost on lawns is not difficult provided reasonable care is taken that the material is friable. It may be broadcast by hand, but on large lawns and greens a distributor may be used and one of the band type will sow up to 8 oz. per sq. yd. of moist compost. Other machines of the centrifugal type will also distribute it when dry enough.

Many of the secrets of good composting lie in the after treatment of the dressed turf. The material should always be worked in by means of a chain mat or a drag broom, the object being to work the friable material among the bases of the grass shoots. This process also leaves more of the material in the hollows and less on the humps, so improving the surface. Composting of very large areas of turf is of course precluded, and where artificials are not used, dung may be applied during the winter months and worked in by means of chain harrows. Dung should not be applied "long" or very lumpy as damage to the turf sometimes follows a dressing. Heavy use of dung is inclined to favour weed increase.

For those who are unable to prepare compost in the accepted sense of the word, using dung, there are various ways in which the organic matter may be supplied. Thus, mixtures of rape meal, soil and sand, or rape meal with sand only, may be used as a source of organic matter. Also malt culms, spent hops, leaf mould and various types of structureless peat are available for

top-dressing mixtures. The various types of sphagnum peat, e.g. ground peat moss, are inclined to lead to a spongy surface when used alone, but in the absence of other forms of organic matter they may be used to the extent of 10 per cent of a mixture with soil and sand. Always, however, it is advisable that these materials should be applied with sand and a small amount of soil. Repeated dressings of peat alone may lead to a surface that is impervious to water and that dries out readily in drought. The above-mentioned materials may be used in various proportions to suit the conditions, but a useful proportion is 1 part of medium loam soil, 2 parts of sharp sand, and 1 or 2 parts of the organic matter.

Disintegrated sewage sludge is also a material that can be obtained in certain districts for top-dressing purposes. Sewage sludges that contain more than 1 or 2 per cent of free calcium carbonate should be avoided. Some of the sewage sludges obtainable in the woollen districts of Yorkshire are above average in nitrogen and have been put through a steaming process that amounts to sterilization.

Autumn top-dressing by means of sand is also important, particularly on heavy soils. Sand chosen for the purpose should always be sharp and gritty, and a good average pit sand should contain at least 60 per cent of particles passing through a 0·5-mm.* and over a 0·2-mm. sieve. Sand containing much material greater than 2 mm. or more than a few per cent below 0·2 mm. should be rejected. In coarse sand for wetter soils about 20 per cent passing through a 2-mm. and over a 1-mm. sieve is permissible. A ton to 600 or 700 sq. yd. is a usual rate on heavy soil and it should be worked into the surface, preferably while growth is still active. There is generally a good deal of controversy as to whether inland sand or a sea sand should be utilized, but no hard and fast rules can be laid down. Inland sands are almost invariably free from lime, whereas sea sand may contain from 1 per cent up to as much as 60 per cent of calcium carbonate. The use of sea sand containing a high amount of shell will act in the same way as a dressing of lime, and experiment has shown that it will favour the softer-growing types of grasses and earthworm activity. It would, however, be foolish in seaside districts where sea sand can be obtained for the carting, to import inland sand from a distance. The use of sea sand is some-

* 1 mm. = 0.0394 in.

times justified on turf that has become too lime deficient when a small dressing of calcium carbonate is beneficial to correct this.

Sand acts in two ways: it dries the surface and leads to increased tillering of the plants, so giving a greater turf density. Sanding, which is a winter and early spring job, can be abused like any other dressing, and applications should not be so heavy as to smother the grass or to give a thick layer in the soil. Should this happen there will be a tendency in future years for the turf to form a cleavage plane at this point.

Other materials of use in top-dressing turf are charcoal and coke breeze. Charcoal gives excellent results as a top-dressing and has the advantage that it can be bought carefully graded. For wet places $\frac{1}{8}$-in. and $\frac{1}{4}$-in. mesh is used, whilst $\frac{1}{16}$-in. mesh is more suitable on firmer, well-established turf. There is often a marked deepening of the colour of the grass following an application of charcoal, but the cause of this is not fully understood. The rate of application is from $\frac{1}{2}$ to 2 lb. per sq. yd. The only point in which coke breeze has an advantage over charcoal is in respect of price, but experience has shown that it is inclined in after years to cause cleavage of the turf and restriction of root development. On lawns or fairways on very wet heavy soils coke breeze may be used to firm up the turf, but it must not be used on playing fields and sports grounds as its presence is likely to lead to injuries to the players.

Whatever the top-dressing it is important that it should be worked into the turf after application using some form of harrow. On small areas a coir or chain mat, or a drag brush, may be used, and on large areas a chain harrow or bush harrow (made from gorse, birch or thorn branches lashed to a hurdle) should be hauled by horse or tractor. Coke breeze should be rolled in after harrowing.

Chapter Sixteen

Fertilizers and Their Practical Use

o the majority of lawn owners, manuring or fertilizing is the first essential to betterment of the turf, but there is an unfortunate tendency to ignore other factors and so fail to obtain the maximum benefit and best value for money spent. Thus, unless surface drainage is correct and the soil is open and friable there will be a poor response, while the water supply during drought must be adequate if the fertilizer applied is to be effective. A thin sward, poor in colour, with moss and weeds encroaching, in all probability requires manurial treatment, but other factors must also be taken into consideration in deciding upon the course to adopt.

It is common knowledge nowadays that growing plants require nitrogen, phosphorus, potassium and calcium (usually referred to as nitrogen, phosphoric acid, potash, and lime) to maintain a healthy growth and development. In addition, however, minor elements such as sulphur, magnesium, manganese and boron are required in very small amount, but they are normally present in the soil in sufficient quantity, so that only rarely is there any response from their addition to the soil. The addition of nitrogen, phosphoric acid and potash is necessary for the growing plant in relatively large amount, and fertilizer treatment aims at maintaining the supply of these essential plant foods.

Turning from the general to the particular, if these elements are to be applied to grass they must be chosen with due regard to the soil and the purpose for which the grass is intended. Thus, the efforts of the farmer to increase the bulk of herbage, improve the chemical analysis of the crop, and favour lush grasses and clovers, are diametrically opposed to the aims

of the lawn owner, who is unconcerned with analysis, does not want bulk, and certainly does not wish to encourage clovers.

The finer grasses, the bents and fescues are found growing naturally on poor, infertile and often acid soils that are low in phosphates and potash, and evidently in the uncultivated state these grasses are able to exist in the presence of small amounts of these manurial elements. On the lawn, however, these grasses are growing under very different conditions, and experiments have shown that frequently-mown grass removes much less nitrogen, phosphorus, and potassium than when cut less frequently.

Of the three elements, nitrogen is removed by the growing grass in greatest quantity, and it is this ingredient that gives the most striking and visible response as regards vegetative growth or leaf production. When a pile of clippings is removed from a lawn it is not always realized how much plant food is being taken away. Approximately 80 per cent of the weight removed is moisture, a figure that is lower in dry weather, whilst the remainder consists of the organic matter built up by the grass plant through photosynthesis together with the ash derived from the minerals absorbed by the roots. This ash contains the phosphorus, potassium, calcium, magnesium and other minor minerals. In some experiments carried out at St. Ives [31] the clippings mown off two bent and fescue swards were collected, dried and weighed throughout the season, and analyses were carried out upon the dry produce. Half of each sward was subjected to monthly dressing with nitrogen as sulphate of ammonia, whilst the other half was left as a control. The differences in yield, analysis and withdrawal of nutrients on an average basis, between species and treatments, is strikingly shown in the following tables (p. 115).

The figures show that Chewing's fescue makes greater demands upon soil nutrients than the bent, and that with both species the withdrawal of nutrients is greater after fertilizing with nitrogen. The application of sulphate of ammonia, when compared with the controls, gives a higher percentage of nitrogen in the clippings and a slightly lower lime content, but phosphate and potash, while greater in the bent, are lower in the fescue.

[31] *Jour. Bd. Green. Res.*, 1932, II, No. 6, 196.

Mean Analysis of Two Turf Grasses under a Regular System of Mowing

Species	New Zealand Bent		Chewing's Fescue	
Treatment	Control	S/A	Control	S/A
	Per cent	Per cent	Per cent	Per cent
Nitrogen	3·23	4·65	3·29	4·29
Phosphate as P_2O_5	0·89	0·96	0·92	0·84
Potash as K_2O	2·56	2·70	2·27	2·03
Lime as CaO	0·95	0·62	0·79	0·59
Mean Yield, lb. per acre	1,200	2,100	1,840	3,000

Mean Yield of Plant Nutrients in lb. per Acre

Species	New Zealand Bent		Chewing's Fescue	
Treatment	Control	S/A	Control	S/A
Nitrogen	38·6	97·6	60·5	128·7
Phosphate as P_2O_5	10·7	20·2	16·9	25·2
Potash as K_2O	30·7	56·7	41·8	60·9
Lime as CaO	11·4	13·0	14·5	17·7

No phosphate or potash was used on these plots so that all the amount of these elements found in the clippings has been derived from the soil—a striking feature being the relatively high amount of potash removed and presumably formed from the degradation of the felspar in the particles of this boulder clay soil. Where the nitrogen has been given the percentage of calcium is lower so that in spite of the increase in yield the total amount of calcium removed is increased very little.

It is commonly asserted by lawn owners and greenkeepers alike that frequent mowing results in increased loss of soil nutrients, but actually the more often a lawn is cut the less nitrogen, phosphate and potash is taken from the soil. This is shown in the accompanying table, in which the relative amounts of nutrients taken up by two species under two systems of mowing, are compared:

Relative Amounts of Nitrogen, Phosphate and Potash Removed from Two Species under Two Systems of Mowing

(Nitrogen uptake from Chewing's fescue mown weekly being expressed as 100.0)

Nutrient	New Zealand Bent		Chewing's Fescue	
	Mown Weekly	Mown Thrice Weekly	Mown Weekly	Mown Thrice Weekly
Nitrogen (N)	91·6	80·9	100·0	85·6
Phosphate (P_2O_5)	19·8	17·7	21·0	18·9
Potash (K_2O)	57·5	54·2	61·3	57·1

The poverty-stricken appearance of fine lawns that are constantly mown is often due not so much to impoverishment as to repeated defoliation, i.e. mutilation of the grass, and here the first step to improvement would be a raising of the blade of the mower.

As already pointed out the main plant food removed in the clippings is nitrogen, and as nitrogen favours leaf growth it is necessary to supply this element periodically, and the form in which it is applied is of considerable importance. Lesser amounts of phosphate and potash are removed from the soil, and whilst some of the requirement is satisfied by compost dressings and some by soil degradation it is nevertheless necessary that occasional use be made of fertilizers containing these nutrients. Whilst such dressings may be applied with advantage, especially on poor soils, their continued heavy use inevitably leads to a mixed herbage and lush growth with a gradual reduction of the finer bent and fescue grasses.

The presence of nitrogen in the soil in a form available for plant growth is thus a most important factor, and there is a complex cycle of changes that will determine the form and fate of naturally-produced nitrogen as well as that added in fertilizers. Living in association with leguminous plants certain bacteria are found in small nodules attached to the roots, these having the power of fixing atmospheric nitrogen and releasing a portion of it for the use of the plant. With the breakdown of these nodules and the roots, the available nitrogen in the soil is increased and consequently the growth of adjacent plants is improved. This is the explanation of the improvement in the

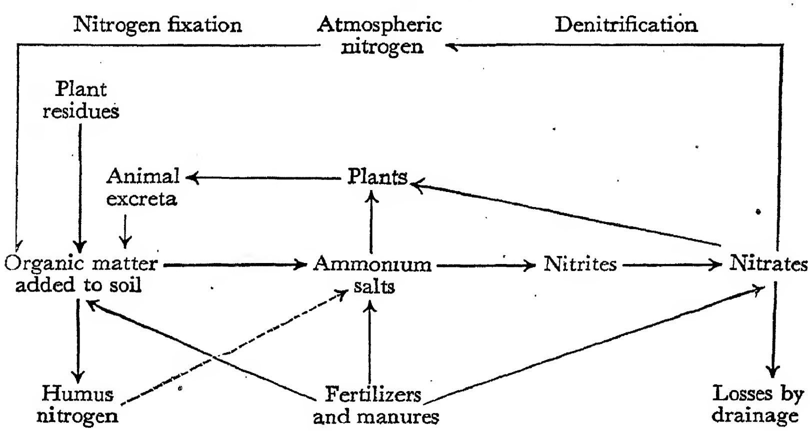
vigour that has been observed to follow the invasion of poor turf by clover.

In addition there are certain soil bacteria that are able to fix atmospheric nitrogen in the soil and convert it to their own use, after which on the death of the organism it is released. Other bacteria in the soil are concerned with nitrification and convert ammonium compounds to nitrites and nitrates. Then there are bacteria responsible for the decay and breakdown of organic plant residues as applied in compost or derived from decaying roots and leaf clippings. They also decompose the remains of soil organisms, releasing in these processes ammonium compounds that are again oxidized to nitrates by the nitrifying bacteria. The whole process is a series of linked reactions to which the grass is attached as the principal remover of nitrate for building up protein matter.

The cycle of changes is further complicated by certain bacteria that (in conditions of bad aeration or water-logging) cause the reduction of nitrites and nitrates to ammonia, and by other bacteria that are capable of oxidizing organic matter and giving off free atmospheric nitrogen. Fortunately, in soil the activity of the latter group is small, and they are mainly associated with dung heaps, where considerable losses of this element may result.

Finally, there is the loss of nitrate in the drainage water, and this is apt to occur before the nitrate is taken up by the plant. The linking up of the various changes may best be shown diagrammatically as follows:

Diagram Showing the Nitrogen Cycle in Soils



It was once believed that green plants could only take up nitrogen in the form of nitrate, so that ammonia had to be oxidized to nitrite and then nitrate by bacterial activity before becoming useful to the plant. Evidence is accumulating [32] that plants can take up some of their nitrogen directly as ammonia without the intervention of bacteria. Certainly from observations on bent and fescue grass plots at St. Ives the rapid visible response from ammoniacal fertilizers suggests that this is so. This would no doubt, if true, in part account for the rapid improvement made to the turf of these grasses by fertilizing with ammonium compounds.

Combined nitrogen for use by growing plants may be applied artificially as a fertilizer in various forms, as also can the phosphatic and potassic manures, and it may be well to describe some of these and their uses in lawn upkeep and greenkeeping.

Nitrogenous Fertilizers. Amongst the fertilizers in this group there is a wide range of materials either of manufactured origin or derived as waste matters often from industrial processes. Undoubtedly the most extensively used nitrogenous fertilizer for turf is sulphate of ammonia, which was formerly a by-product in the coke and coal industry but is now very largely produced as a synthetic product from atmospheric nitrogen and hydrogen combined at high pressure. Sulphate of ammonia so produced is a whitish odourless crystalline salt, soluble in water and sold with a guaranteed analysis of 20·6 per cent of nitrogen. As some forms contain a small percentage of sulphuric acid it is always advisable to purchase the quality known as "dry neutral" which has less than 0·025 per cent of free sulphuric acid.

The extensive use of sulphate of ammonia for fine turf probably began with the pioneer American investigations of Piper and Oakley, who showed that it was possible to start with a weed-free turf and maintain it thus by systematic dressings of this fertilizer. This finding has been amply confirmed by many experiments carried out at St. Ives in recent years. It has long been known that sulphate of ammonia tends to make the soil acid. The repeated applications in the American trials led to an increase in the acidity of the soil, so that the tendency was to account for the non-appearance of weeds by this induced acidity. It is important to draw a distinction between the main-

[32] Richardson, H. L.: *Agric. Progress*, 1933, X, 160.

tenance of freedom from weeds in turf and their eradication by sulphate of ammonia in a turf that is already weed infested. The two aspects are quite different and sulphate of ammonia has undoubted value for the second purpose though the reasons for the decline of the weed population must be sought in various directions. This subject will be reviewed later.

Sulphate of ammonia is one of the most popular turf fertilizers, though like many other materials that give good results it can be abused, and much harm can also result from faulty application. The rate of dressing should not exceed 3 lb. per 100 sq. yd. The nitrogen in it is quick acting and leads to a vigorous growth of grass and so to a denser and thicker sward. The nitrogen in sulphate of ammonia is retained in the surface layers of the soil so that there is no likelihood of it being lost in the drainage water, which is likely when nitrate of soda dressings are given.

Another quick-acting nitrogenous fertilizer is nitro-chalk, which appeared on the market some few years ago as a synthetic product. It is made from the fusing together of ammonium nitrate and calcium carbonate to give a granular compound, which is comparatively easy to distribute though best spread on fine turf with a carrier of compost. Half the 15·5 per cent of nitrogen is present in the form of ammonia and half as nitrate, while 48 per cent of nitro-chalk is calcium carbonate. For use on acid turf nitro-chalk has advantages, though on putting greens the sudden stimulus to growth is inclined to encourage disease, and plot trials show that long-continued and regular use encourages worm and weed invasion.

For some years a synthetic form of nitrogenous fertilizer, known as calcium cyanamide, has been on the market, and latterly the percentage of nitrogen has been increased to the same figure as that for sulphate of ammonia, and the mechanical condition has been improved. It may now be obtained in granular form; 20 per cent of free lime is present and the fertilizer compares favourably in price with other fertilizers. It has advantages on acid soils but its use on fine turf is limited, since it is apt to scorch.

Nitrate of soda containing 15·5 to 16 per cent of nitrogen is very rapid in action and forms a useful plant stimulant. The material is crystalline or granular, but the purchase of nitrogen in this form is more expensive than as sulphate of ammonia.

Nitrate of soda is a valuable source of quick-acting nitrogen for rapidly bringing on turf, but continuous use tends to injure the soil tilth and leads to caking in dry weather. Continued use on experimental turf plots has led to worm and weed invasion and to a soft spongy turf, particularly in wet weather. The turf in these trials, whilst undoubtedly more drought-resistant than plots receiving an equivalent amount of nitrogen as sulphate of ammonia, is more susceptible to disease. If nitrate of soda is applied immediately before heavy rain, losses of nitrate are easily incurred.

Only a little work has been done with nitrate of lime, but this fertilizer, which is seldom used in practice, gives results on turf similar to those due to nitrate of soda.

There are various other nitrogenous compounds on the market, many of them being waste products. Of these perhaps soot is the best known in turf maintenance and it is a variable commodity containing anything from 2 to 11 per cent of nitrogen, the higher grades usually being obtained from kitchen chimneys and the lower grades from boilers. The bushel weight is an important indicator of the nitrogen content. Thus soot containing 4 per cent of nitrogen has a bushel weight of 24 to 28 lb., whereas a good sample containing 7 per cent of nitrogen will weigh approximately 15 lb. to the bushel. Average samples, however, only contain 2 per cent of nitrogen with a bushel weight of about 40 lb. Soot is often applied to turf, but it is so unsightly that its application must be made with circumspection, and in practice the best plan is to mix the soot with compost or top-dressing and to apply it when rain will wash it quickly into the soil. The darkening in soil colour following the use of soot is advantageous since it tends to give a warmer soil which radiates heat more slowly.

A common nitrogenous fertilizer is dried blood, obtained from slaughter-houses. The material is prepared by the precipitation of the protein matter, which is then dried to brown flakes giving a product somewhat variable in composition but usually containing 13 per cent of nitrogen. The nitrogen is rather less quickly available than that in sulphate of ammonia but plots comparing it with sulphate of ammonia show that it has no effect in reducing weed infestation. In its favour it may be said that dried blood is useful on sandy soils, is safer to use, and gives a more drought-resistant turf than sulphate of ammonia. Being

of a friable and dry nature it is often included in proprietary mixtures.

Hoof and horn meals, derived from the glue industry, depend for their value as turf fertilizers upon the fineness of grinding. Containing 12 to 14 per cent of nitrogen they form a source of slow-acting nitrogen but should not be used where a rapid response is required.

Leather waste containing as much as 6 per cent of nitrogen is sometimes used in cheap mixed fertilizers as a means of increasing the nitrogen content, but it is relatively unavailable and can only be regarded as a drier and conditioner for mixing purposes.

Mention may be made of other waste materials such as shoddy derived from the textile industry, which may contain from 5 to 14 per cent of nitrogen. The material is only very slowly decomposed in the soil and so its main use for turf purposes is as a bulking agent, though it may also be used in compost heaps that are to remain untouched for several seasons.

Some forms of sewage sludge are useful for top-dressing provided they do not contain more than 1 or 2 per cent of calcium carbonate.

The waste-product nitrogenous manures described above are all of animal origin or wastes from factories and towns. There are other materials, of vegetable origin, which are quite useful for the treatment of turf. Of these rape meal with 5·5 per cent of nitrogen and castor meal with a similar percentage may be mentioned. Rape meal when applied judiciously to turf gives quite good results; if used excessively it is apt to encourage earthworm activity. It is a useful material for application to light, sandy soils. Malt culms, derived from the rootlets of germinated barley in malting, contains 3·5 per cent of nitrogen and is also used as an organic fertilizer on greens or lawns. It may be used as a straight dressing at 1 or 2 oz. per sq. yd. or mixed in a compost heap to decompose before application. Spent hops containing about 3·5 per cent of nitrogen may, when finely ground, be used for direct application or in the compost heap. Finely-ground peat, which has been extensively advocated in recent years for turf upkeep, contains about 1 per cent of nitrogen and forms a useful ingredient of compost mixtures; the nitrogen, however, is relatively unavailable.

Various organic wastes such as feathers, greaves, hair, rabbit flick, slaughter-house refuse, fish waste, brewing and distillery

wastes and pomace are sometimes offered for turf purposes, but all these materials are unsuitable for use unless they have passed through a preliminary period of decomposition in the compost heap. In coastal districts supplies of seaweed are often obtainable, but here again previous decomposition is necessary. Many lawn owners, managers of playing fields and golf courses, pay high prices for organic materials, which, with a little trouble, they could easily prepare themselves by building into compost heaps such materials as the above, as well as grass clippings, shoddy and similar materials.

Phosphatic Fertilizers. Phosphates serve several important functions in the soil. They tend to encourage earlier development of the young plant, and as has been shown [33] favour the development of roots in turf; they also counteract the forcing action of nitrogenous manures used alone, and in agricultural crops, improve the grain and the feeding value of fodder. In greenkeeping perhaps the best-known phosphatic manure is raw bone meal, which has long enjoyed a position of high esteem for turf purposes. Many excellent bowling greens are maintained by the annual application of high weights (6 to 7 cwt.) of bone meal, and it appears likely that the good results obtained can be attributed more to the nitrogen content of the bone meal than to the phosphoric acid present. A good quality bone meal contains about 4 per cent of nitrogen and 20·5 per cent of insoluble phosphoric acid, and it is generally described as a phosphatic manure even though it contains this appreciable amount of nitrogen. The mechanical condition of bone meal is an important point to note when purchasing bone meal since many samples on the market are too coarse for application to turf. It should be finely gristed but not dusty.

Another phosphatic material derived from bones is steamed bone meal, which is obtained by extracting the gelatine from the bone meal, thus giving a reduction of the nitrogen percentage and increase in the phosphoric acid, a usual analysis being 0·75 per cent of nitrogen and 27·5 per cent of phosphoric acid. On account of its lower nitrogen content, steamed bone meal is not so effective as bone meal on turf, but it is, of course, a valuable source of phosphoric acid and is often in a finer state of division than bone meal. Bone charcoal, prepared for use in

[33] *Jour. Bd. Green. Res.*, 1931, II, No. 5, 119.

the manufacture of sugar as a decolorizer, may often be obtained under the name of spent bone char. This material is black in colour and contains from 1·5 to 2 per cent of nitrogen and from 28 to 35 per cent of insoluble phosphoric acid.

All bone manures are particularly useful on acid soils containing a high proportion of organic matter, and they are therefore suitable for application to turf.

Superphosphate differs from most other phosphatic fertilizers in that the phosphoric acid is soluble in water as distinct from that in bone meal, basic slag, and rock phosphate, which is insoluble in water. The full name for this material is superphosphate of lime, but it is important to avoid the error of assuming that the lime referred to behaves like true lime or limestone. Besides the calcium phosphate present in it the other lime compound is gypsum. Two grades of this fertilizer, containing respectively 14 and 16 per cent of soluble P_2O_5, are commonly used, and the 16-per-cent material is the better value of the two; lately an 18-per-cent grade of superphosphate has been advertised. The material is made by the interaction of mineral phosphates and sulphuric acid, and is a development of the original manufacture of superphosphate from bones by Lawes. Although the phosphoric acid in superphosphate is soluble in water, when applied to soils it rapidly becomes insoluble but, being in a very fine state of division in the soil it gradually becomes available to the growing plant. During investigations carried out at St. Ives on the manuring of turf species, superphosphate has been found exceedingly valuable, and benefit has been shown in a marked improvement in the density of the turf and its resistance to drought, the latter no doubt being a reflection of the improved root development. Superphosphate, when applied in neat form to turf, is apt to scorch the herbage, and it should therefore only be given when mixed with sufficient carrier. On calcareous soils superphosphate is found to be superior to bone meal.

Among the insoluble forms of phosphatic manures mention must be made of basic slag, a product derived from the manufacture of steel. It is not necessary to go into details of manufacture in this account. In purchasing basic slag it is important that the fineness of grinding should conform to the accepted standard, and at least 80 per cent of the material should pass through the British Standard test sieve, mesh No. 100. Basic slags are

sold on their content of phosphoric acid, which ranges from 8 to 18½ per cent, but there are also differences in solubility as determined by the accepted test with citric acid, the high soluble group having 80 per cent or more soluble, while the other has 40 per cent or less soluble. The activity of the phosphate is related to the value for the solubility and it may be said that 1 cwt. of basic slag will yield approximately ⅔ cwt. of lime for neutralizing purposes. Basic slag has not received much attention in greenkeeping, and perhaps this may be attributed to its well-known reputation for encouraging clover. The general improvement of pastures following basic slag dressings is very largely due to the increase of leguminous plants. Old turf composed of bent will respond readily to dressings of slag, but there is a danger that by using it worms, as well as clovers, which may be latent as small plants, may be encouraged. Where turf conditions indicate a trial with slag, the dressing should not exceed 5 to 7 cwt. per acre. In many instances very acid turf would undoubtedly respond to the use of slag, and experiments are in progress to test it out against other phosphatic dressings. The alkalinity of slag makes it particularly useful on peaty and acid soils.

Finally, mention must be made of mineral phosphate, which contains from 25 to 39 per cent of phosphoric acid, and is important from the point of view of relative cheapness. Trials are in progress on turf as there appear as yet to be no scientific data regarding its value for this purpose.

Potassic Fertilizers. It will be remembered from the figures given for the amount of potash removed in the clippings from certain experimental plots that potash was the second in order of importance removed. The rôle of potash in the plant is associated with the manufacture of carbohydrates by the green leaf, and is linked with nitrogen in controlling growth, but obvious responses to potassic manures are not obtained; indeed, experimental plots under observation for a period of fourteen years have not yet shown any marked response, though there is evidence that swards receiving potash tend to remain greener during the winter months than those not receiving them.

The usual forms in which potash fertilizers are obtained may be placed in two groups, high-grade salts such as sulphate of potash containing 48 per cent of K_2O and potassium chloride

or muriate of potash containing 50 per cent, and low-grade materials such as 30-per-cent potash salts, 20-per-cent potash salts, and kainit containing 14 per cent K_2O. The 30-per-cent potash salts contain anything from 24 to 27 per cent of common salt, and some magnesium sulphate. Potash manures have not been used extensively in lawn and green upkeep, and most proprietary mixtures for dressing lawns are very low in this fertilizer. Perhaps this is due to the fact that potassic fertilizers when applied to agricultural grass land favour the growth of clovers, and indeed it has been suggested that the application of slag to grass land results in the release of potash which in turn favours the clovers. The use of a fertilizer containing potash on clover-free turf cannot miraculously lead to clover invasion, and on experimental plots at St. Ives no evidence has been found for the belief that potash encourages clovers. This may be because in most instances high nitrogenous manuring inimical to clover has also been carried out. High nitrogenous manuring as required for turf production involves the uptake of high amounts of potash, and it is possible that improved turf, freer from disease, would be obtained if potash were used in greater quantity, especially on light soils.

Concentrated Fertilizers. In this group may be placed such materials as urea, ammonium phosphate, ammonium nitrate, and potassium nitrate. Urea is almost unknown in connexion with fertilizing in this country, but experiments carried out with it at St. Ives have shown that, whilst the grasses respond, there is no reduction of weed growth as happens with sulphate of ammonia or ammonium phosphate, and in fact there is a tendency for weeds to be favoured.

Ammonium phosphate is manufactured in two forms, but only one is produced in this country, namely mono-ammonium dihydrogen-phosphate, which contains theoretically a percentage of 12·1 per cent of N. and 61·7 per cent of P_2O_5. The commercial form contains less phosphoric acid. Large-scale production of ammonium phosphate is carried out, and the material is combined with sulphate of ammonia to produce two series of concentrated fertilizers known as N.P. fertilizers, and when potash is added in addition, as C.C.F's. These are granular in form.

As a source of ammoniacal nitrogen and water-soluble phos-

phoric acid mono-ammonium phosphate can only be compared with a mixture of sulphate of ammonia and superphosphate. It is important to know that whilst the latter contains calcium in the form of gypsum and calcium phosphate, no such calcium is present in ammonium phosphate. In agricultural experiments it has been found that equivalent results are obtained, and the experiments at St. Ives have shown that ammonium phosphate has equivalent weed-killing effects to sulphate of ammonia. American workers have also recorded the beneficial effects of using this compound. The value of ammonium phosphate for producing root development on New Zealand browntop and certain fescues has been shown, and is in confirmation of work carried out in America. Ammonium phosphate plots have a tendency to be lighter in colour, but denser, than those receiving sulphate of ammonia. They are not quite so dense as those receiving sulphate of ammonia and superphosphate. Ammonium phosphate has an undoubted value in lawn upkeep, and it is to be hoped that more use will be made of it in the future. A suitable rate of application would be 4 lb. per 100 sq. yd.

Miscellaneous Fertilizers. For convenience quite a number of materials of interest in lawn upkeep may be grouped under this heading. Of these poultry manure is perhaps the most prominent at the present day, and good samples of kiln-dried poultry manure contain about 4·3 per cent of nitrogen, 1·3 per cent of phosphoric acid and 2·9 per cent of potash. When properly prepared the material is friable and bulky, and based upon its manurial ingredients would be worth approximately £6 per ton, though some allowance must be added for drying, grinding and rebagging. Many lawn owners will be in a position to obtain poultry manure, perhaps in small quantity, but relatively cheaply, and if so it is important that the material be allowed to dry quickly so as to prevent fermentation and loss of ammonia. If used on turf in the wet fermenting condition damage to the grass is certain to result. The material should be broken up finely and mixed with a carrier before spreading on the turf, or better still, composted. On a nitrogen basis poultry manure compares very favourably with rape meal and malt culms, though its nitrogen is more easily available.

Under the heading of miscellaneous materials one may include various forms of sewage sludge that are available on the

market as straight fertilizers. As already stated, sewage sludge for use on turf should be lime-free, and in the woollen districts of Yorkshire sewage sludge having a nitrogen content above the average is obtainable. This material contains 2·5 per cent of nitrogen, 0·3 per cent of phosphoric acid, and a trace of potash. It is bulky and can therefore be used for spreading in relatively high amounts on turf or as a bulking agent for more concentrated artificials.

Fish guano is another material that is often used for turf dressings, or as an ingredient of proprietary mixtures. A typical fish guano contains from 6 to 7·5 per cent of nitrogen, 5 to 7 per cent of phosphoric acid, and 0·5 to 0·8 per cent of potash. It has the disadvantages that it is variable in quantity and analysis, and often has an objectionable odour. A more uniform fish manure is white fish meal, which has the further advantage of having a less objectionable odour; it contains a higher percentage of nitrogen and phosphoric acid, up to 10 per cent of each, and about 1 per cent of potash. This material may be regarded as a useful substitute for Peruvian guano, of which supplies are to-day rather scarce. It has a high reputation in turf upkeep, in part owing to its safeness on account of the bulk and relatively low analysis. Good Peruvian guanos contain from 10 to 18 per cent of nitrogen, some of which is readily available but most is slower acting. The material is, however, a very variable commodity, older deposits being browner with a lower nitrogen and higher phosphate analysis. It should always be bought on the basis of the analysis. The high price is in part due to the high transport costs.

Various types of guano are made from market and town wastes, and some of them are valuable for turf purposes.

In recent years a waste product from the distilling industry has appeared on the market. This contains 4·9 per cent of N, 5·0 per cent of P_2O_5 and 3 per cent K_2O. At times ground cocoa husk or shell is offered, an average analysis being 3·85 per cent of N, 1·87 per cent of P_2O_5 and 3·0 per cent of K_2O. Both the above are bulky materials, and can be utilized in mixed manures, compost heaps, and even for direct application to the turf. Spent mushroom manure is sometimes procurable.

A list of fertilizers and their analyses will be found in Appendix One (p. 284).

Chapter Seventeen

The Evaluation, Purchase and Compounding of Fertilizers

Most amateur lawn owners think of fertilizers in terms of proprietary compound mixtures containing the three main plant foods, and ideas of fertilizer costs are often based upon the prices paid for these preparations. Unless the lawn owner is only concerned with a small area or wishes to avoid a little additional trouble he can mix compound fertilizers for himself or, alternatively, submit a formula to a reputable merchant with the request that the compound be made up. Hard and fast formulæ are difficult to lay down in view of the varying soils, prices and turf requirements.

Complete proprietary mixtures vary widely in analysis according to the views of the supplier; thus examination of the declared analyses of a number shows a variability of the nitrogen from 3 up to 15 per cent, of the phosphoric acid from 2·5 up to 16 per cent, and of the potash from 0·5 to as much as 5 per cent. It is customary in such mixtures to include the nitrogen in more than one form in order, it is stated, that it should become available by degrees. This involves the use of organic nitrogen-containing compounds. Phosphate may also be included in different forms. In support of this custom it is argued that if all the nitrogen is included in an inorganic form such as sulphate of ammonia, much of it will be lost in the drainage water, though it is a well-established fact that ammonia is held in soils and the losses are very small. Phosphate is rarely lost in appreciable quantity in drainage waters.

A simple method of manuring intensively-managed turf is to apply a complete fertilizer in spring, and to follow with

several dressings of a nitrogenous fertilizer such as sulphate of ammonia during the season.

Compound Manures. A generalized basic compound fertilizer should contain:

5 to	7%	nitrogen
10 ,,	15%	phosphoric acid
2 ,,	4%	potash

Such a mixture may be used in spring at 2 to 3 oz. per sq. yd. if further nitrogen is to follow. A mixture falling within these limits could be compounded by mixing together the following materials:

15	parts by weight	sulphate of ammonia
15	,, ,, ,,	dried blood
40	,, ,, ,,	fine bone meal
25	,, ,, ,,	superphosphate
5	,, ,, ,,	sulphate of potash

This mixture, it will be seen, derives its nitrogen from the first three ingredients. The phosphate is present in two forms. It must not be assumed that this mixture is generally applicable under all conditions, but it is included here as a guide as to how mixtures may be compounded. It is impossible to prescribe for all conditions, and there will be times when such a mixture would be unsuitable and where some other recipe would be more desirable. Further, there is a choice of materials available for compounding mixtures of this type, so giving a number of products having the same final analysis of plant foods.

The use of sulphate of iron in conjunction with mixtures such as the above is now usual, and 10 per cent may usefully be added, some of the other ingredients being proportionately reduced.

Mixing. Certain fertilizers do not mix satisfactorily. For example, ammoniacal manures should not be mixed with materials containing free lime, such as basic slag or certain rock phosphates, because free ammonia is likely to be lost. Sulphate of ammonia mixes well with superphosphate, bone and fish meals, nitrate of soda and potash manures. Compound mixtures of sulphate of ammonia and superphosphate, especially if potash

salts are present, are inclined to set hard on storage, but the addition of bone flour or castor meal as a drier, will largely prevent this. Mixtures containing nitrate of soda are apt to become moist and sticky unless a drier is added (see Fig. 13).

A complete table showing the compounds that may be mixed and that may not be mixed is given in Appendix Two (p. 286).

In preparing a mixture the method adopted depends on the quantity concerned. If the amount is relatively small no difficulty should be encountered in ensuring intimate intermingling. Where large lots are involved it is advisable to spread separate layers of the ingredients one upon the other and then to throw the heap up into a conical pile, later digging this down and passing it through a screen. Small quantities are best handled at a time, and it is advisable to allow the freshly-mixed material to stand in a heap for a few days to "cure", when it can be broken down, screened and bagged, after which it will not easily set. For those without adequate facilities for mixing it is better to send a recipe to the merchant to mix on his premises.

When mixing materials it is important that all lumps should be eliminated, and the mixture should be in good fine powdery condition so as to facilitate even distribution. Even distribution is most important when treating turf, as a lump of, say, superphosphate would scorch the grass, and as regards nitrogenous manures a lack of uniformity in colour will result unless the material has been spread evenly. It should be realized that when fertilizer is applied to turf, there is practically no lateral spread of the effect, so that a heavy local dressing will only cause improvement of the area immediately surrounding it. Only fine-ground qualities of hoof and bone meals should be used otherwise difficulties in mixing and spreading result.

Materials that have to be stored should be kept in a dry place, or they are likely to become lumpy. Nitro-chalk is apt to absorb moisture. Even some of the raw materials used for preparing mixtures, e.g. sulphate of ammonia and nitrate of soda, are liable to lose condition, though it must be said that the granular nitrate of soda and the dry neutral sulphate of ammonia show a great improvement on the old materials.

The Purchase of Manures. The Fertilizer and Feeding Stuffs Act of 1926 requires that the seller of artificial manures shall

make a written statement of the percentages of the plant food present under the following heads:

Nitrogen (N)
Soluble phosphoric acid (Sol. P_2O_5)
Insoluble phosphoric acid (Insol. P_2O_5)
Potash (K_2O)

This holds good with the exception of a sale of two or more articles that are mixed at the request of the purchaser before delivery and also to sales of quantities less than 56 lb. if taken from a receptacle upon which the analysis is prominently displayed. The Act applies to fertilizers only and not to materials mixed together and sold under a branded name as "lawn food". All too often with lawn fertilizers statements such as "equal to ammonia", "total phosphate of lime", "sulphate of potash", are used in addition to the figures required by law. Should the above be the only statement made then it is illegal. This can only be regarded as a device to enhance the apparent value. Thus, a well-advertised proprietary fertilizer containing 1·5 per cent of nitrogen might be much more attractive to some customers if sold as containing 7·2 per cent sulphate of ammonia, though both figures convey the same information.

The analysis of a compound manure, such as already given, may readily be calculated by multiplying the proportion of each constituent in the mixture by its percentage content of nitrogen, phosphoric acid or potash and dividing by the total weight. Thus, in the mixture already given the percentage of nitrogen derived from the sulphate of ammonia may be calculated by multiplying the 15 parts of sulphate of ammonia by 20·6 and dividing by 100: i.e. 15 × 20·6 ÷ 100 = 3·09 per cent of N.

This may also be done for the other ingredients, giving a final analysis as follows:

15 parts by weight	sulphate of ammonia (20·6% N)	=3·09%	Total N =
15 „ „ „	dried blood (13% N)	=1·95%	
	5%		
	5%		ns
25	superphosphate (16% Sol. P_2O_5)	=4·0%	Sol. P_2O_5
5	sulphate of potash (48% K_2O)	=2·4%	K_2O

Valuation. Other things being equal, the value of an artificial fertilizer depends upon the quantities of the principal manurial

ingredients present, and by using the percentages of these and the price paid a simple system of comparative valuation may be carried out.

If the price per ton of a straight fertilizer containing one form of plant food be divided by the percentage of the plant food present, the deduced cost is described as that of a "unit". By a study of such unit values it is possible to select the most economical manure and to protect oneself against fraud when buying basic or special manures.

Taking sulphate of ammonia (20·6 per cent of nitrogen) as an illustration, and the delivered price per ton as £8 (this is not necessarily a current price) and dividing by 20·6 gives a "unit" price of 7*s.* 9*d.* The unit price of nitrogen varies with the commodity. Thus, in nitrate of soda, a unit of nitrogen costs about 11*s.* delivered, and in organic manures like dried blood the figure may be taken as approximately 20*s.* delivered, owing to the special value placed upon this material for use in compound manures for turf. Unless some special outstanding merit attaches to the nitrate of soda and dried blood for a particular purpose, then obviously sulphate of ammonia is the cheapest form of nitrogen among those mentioned. Similarly, if £4 per ton delivered is paid for superphosphate containing 16 per cent of soluble P_2O_5 the unit price of soluble phosphoric acid is 5*s.*, while sulphate of potash costing £10 per ton delivered gives the unit price of potash as 4*s.* 2*d.*

A difficulty is encountered when calculating the unit value of insoluble P_2O_5 in a material like bone meal containing 20·5 per cent of P_2O_5 as well as 3·75 per cent of nitrogen in organic form, and costing say £8 per ton delivered. It is necessary to assign a value to this nitrogen, and taking the outside figure of 20*s.* a unit, a deduction of £3 15*s.* may be made, leaving £4 5*s.* as the value of the insoluble P_2O_5. This figure divided by 20·5 gives 4*s.* 2*d.* as the unit price of the insoluble P_2O_5.

The unit prices of manures are not fixed; they vary with the market price of the materials, but the current prices are published monthly in the *Journal of the Ministry of Agriculture* and some other periodicals.

A simple example of evaluation may now be given. Two parcels of dried blood are offered, the first with 13 per cent of nitrogen at £13 per ton, and the second with 10·5 per cent of

nitrogen, at £12 per ton, both delivered to customer's address. Calculating the unit values shows that in the first sample 20*s*. is the unit value, whilst in the second the unit of nitrogen costs nearly 22*s*., so that better value will be obtained by accepting the first offer.

The valuation of a compound fertilizer, such as already used as an illustration, may be carried out in the following manner:

		s.	*d.*	£	*s.*	*d.*
3·09 per cent of nitrogen	at	7	9=	1	4	0
1·95 ,, ,, ,, organic nitrogen	,,	20	0=	1	19	0
1·5 ,, ,, ,, ,, ,,	,,	20	0=	1	10	0
8·2 ,, ,, ,, insol. phosphoric acid	,,	4	2=	1	14	2
4·0 ,, ,, ,, sol. ,, ,,	,,	5	0=	1	0	0
2·4 ,, ,, ,, potash ,, ,,	,,	4	2=		8	6
			Value	£7	15	8 per ton

To this figure should be added the cost of mixing, usually £1 per ton, as well as an allowance for rebagging and loss of weight. When obtaining competitive prices for the same formula from several suppliers the price quoted is sufficient guide as to value, but if by chance one merchant is only able to supply on the basis of one or more ingredients being of slightly different analysis then the comparative evaluation must be carried out. If sulphate of iron is present it must be valued in a similar manner to the fertilizers.

If a compound ready-mixed fertilizer is being offered and it is desired to calculate whether or not the price quoted is a fair one, some difficulty may be experienced, because although the analysis may be given, no statement is required by law as to the constitution. It is therefore difficult to evaluate, say, the nitrogen, which may have been included in more than one form for a special purpose. Evaluation on units of plant food can readily be done, or some allowance be made on the assumption that perhaps half the nitrogen is organic and valued at say 20*s*. a unit and half inorganic and valued at say 7*s*. 9*d*., the unit price of nitrogen in sulphate of ammonia. In matters of doubt an independent authority should be consulted.

As regards mixtures offered in ready-made form the valuation in arithmetical manner is not always a complete safeguard, because the full analysis of the material may be present but it may not be of much value. Thus, by incorporating ground-

leather waste into a mixture, the percentage of nitrogen can be made to look high, but this material is relatively unusable by the plant and so has little value. It is true that the purchaser receives his nitrogen as advertised, but it is questionable whether the turf will receive its nitrogen this year or next or only 5 or 6 years hence. Purchasers should not be misled by the claim that a manure has a value not indicated by the analysis. Thus, there are some artificials that are sold for greenkeeping purposes with a statement that they are also effective in reducing weeds. This may or may not be true, but it makes no difference to the value of the material as plant food.

Materials like dried blood, rape meal, and guano have some action in improving both the physical texture and water-holding capacity of soils. They cannot therefore be valued solely as plant food, but the quantity used can have very little appreciable effect in improving the physical properties of the soil. In taking 20*s*. as the unit price of organic nitrogen this has been more than allowed for, but a material like dried blood commands a higher price than inorganic nitrogen on account of its reputed value for turf purposes. In lawn upkeep any substantial change in the physical texture of the soil is best carried out by the deliberate use of compost containing organic matter, or by the use of special top-dressing rich in this material.

As stated above high amounts of organic fertilizers may be present in a compound manure but be worth very little owing to the fact that they become available so slowly. The growing plant absorbs its nitrogen in the form of nitrates, i.e. by a rapid process, and the material is very largely used up; but the nitrogen in many materials is not readily available and must be converted to nitrate in the soil. Some materials like sulphate of ammonia, dried blood, rape meal, and guano pass through this change rapidly, but there is always some loss in the process. The risk of loss varies according to the amount of change necessary. It is often stated that quick-acting nitrogen as in sulphate of ammonia is rapidly lost and that organic slow-acting nitrogen is held better, but the reverse is more likely to take place. Of course a rapidly available material may be applied at the wrong time of year when grass cannot respond, so that it is largely wasted, but it is true to say that very slow-acting materials requiring a long process of change involve losses. Slowness of availability should detract from value instead of

adding to it. This may be made clear from an example used by the Ministry of Agriculture in Bulletin No. 36. Thus, £100 due in six years or six months is not worth £100 to-day, so, 100 lb. weight of nitrogen or phosphoric acid or potash that will not become effective until some remote date is less valuable than the same quantity that can be brought into action during the current season.

Organic forms of manures for turf have the advantage that they are safer to use in the hands of the inexperienced, and being more bulky than inorganic they are easier to spread. For use by the amateur, therefore, they have a somewhat enhanced value, but the price they command, even with this allowance, is out of proportion to their real manurial value.

The subject of fertilizers, their valuation and use in turf upkeep has been discussed in this account in some detail because experience has shown that most lawn owners, greenkeepers, managers of sports grounds and golf courses, are largely "in the dark" and often pay prices far in excess of those that should be charged when the fertilizers are regarded as suppliers of plant food.

Chapter Eighteen

Sulphate of Iron

brief reference has already been made to the use of sulphate of iron in conjunction with compound fertilizer mixtures, but as the function of sulphate of iron is not that of a fertilizer, it is necessary that its properties should receive separate consideration. Sulphate of iron has been well known for many years to horticulturists, among whom it is known for its ability to improve the colour of flowers and of the leaves of certain plants. It is sometimes claimed that sulphate of iron assists nitrification and the utilization of phosphate in the soil, but whether these claims will be substantiated by future work remains to be seen. With turf, however, sulphate of iron appears to promote the formation of chlorophyll in the leaves, though iron is not a constituent of the molecule of this complex compound.

Although sulphate of iron has been used for many years as an ingredient of lawn-sand mixtures, it appears to have been first advocated about 1913 for regular use on turf by Dr. C. M. Murray in South Africa, who advised its systematic use in conjunction with sulphate of ammonia. Afterwards it was extensively adopted in this country, first as an auxiliary in weed eradication, and secondly as a means of combating the chlorotic appearance of grass often observed to follow the use of quick-acting nitrogenous fertilizers, such as sulphate of ammonia.

In its crude commercial form sulphate of iron ($FeSO_4.7H_2O$) is obtainable as large blue-green crystals containing 45 per cent of water ($7H_2O$), in chemical combination as water of crystallization, and 20 per cent of iron (Fe). In this form the material is unsuitable for use on turf, though suitable crystals as fine as castor sugar are obtainable from some sources. It has become

customary, however, to use the sulphate of iron in the "exsiccated" or "calcined" form, which is produced by heating the coarse crystals and driving off a proportion of the combined water. After grinding, the resultant material is a fine whitish-green powder having the consistency of flour. In the baking process it is necessary to avoid oxidation to ferric oxide.

Supplies of calcined sulphate of iron on the market are very variable; in some only one molecule of water has been removed, 41 per cent of water still being present, whilst in a well-calcined material 5½ molecules have been driven off, so leaving a product containing about 16 per cent of water. An average quality contains 30 to 35 per cent of water, i.e. 4½ to 5 molecules. Little information exists as to the relative merits of crystalline sulphate of iron and the various grades of the calcined form, but preliminary treatments have not shown any marked difference in the effects. The calcined sulphate of iron, being in a fine state of division, distributes well and mixes easily with other materials.

Early experiments at St. Ives [34] have shown that when sulphate of iron is regularly used with sulphate of ammonia there is a more rapid diminution of weeds than with sulphate of ammonia alone. The end result may be the same, but weed killing is more rapid, and the sulphate of iron imparts a beautiful deep green colour to the turf. Blackman [35] also records a slightly greater weed reduction with sulphate of ammonia plus sulphate of iron as against sulphate of ammonia only, and he obtained similar results with the double salt, ferrous ammonium sulphate. Similar results with the double salt were also obtained in trials at St. Ives.

In some experiments [36] comparing sulphate of ammonia with light and heavy rates of sulphate of iron on plots sown with a mixture of bent and fine-leaved fescue, it was found that the heavier dressing resulted in a decrease of the bent and a proportionate increase of the fescue.

Sulphate of iron helps to induce soil acidity, and although it has been claimed that the sulphate assists utilization of phosphate all the evidence so far indicates that it has the effect of immobilizing phosphate in the soil, converting it into insoluble

[34] *Jour. Bd. Green. Res.*, 1931, II, No. 4, 40.
[35] Blackman, G. E.: *Anns. Appl. Biol.*, 1932, XIX, No. 2, 204.
[36] *Jour. Bd. Green. Res.*, 1931, II, No. 4, 36.

and relatively unavailable compounds. Plot trials have shown that long-continued use of sulphate of iron with sulphate of ammonia may lead to a thin open brownish-black turf slow to respond to rain or artificial watering. Where equivalent amounts of sulphate of iron and sulphate of ammonia plus phosphate were given this condition did not develop. Sulphate of iron also has a tendency, when not supported by fertilizers, to make the soil dry and crumbly. It has a marked inhibitory action on fungi that cause turf disease.

Sulphate of iron confers weed-killing properties on certain fertilizers, which, used alone, do not have this effect. Further reference will be made to the matter under weed control, where the properties of sulphate of iron as a moss killer will also be discussed. The sulphate also has a definite inhibiting action on earthworm activity. Thus, in some trials [37] 10 oz. of sulphate of iron applied in small amounts over four seasons reduced the worm casts from a range of 20 to 40 per sq. yd. to 2 to 20, whilst an application of 13·5 oz. over the same period had reduced the range of casts to 1 to 4 per sq. yd.

The place of sulphate of iron in modern lawn and greens upkeep is now well established, but it requires careful usage if the best results for weed or moss eradication and earthworm inhibition are to be attained.

Further references to the use of sulphate of iron appear in Chapters 21 and 22.

[37] *Jour. Bd. Green. Res.*, 1937, V, No. 17, 97.

Chapter Nineteen

Lime and the Preservation of Soil Acidity

he analyses of dried grass clippings given in Chapter 16 show a figure of less than 1 per cent of lime expressed as CaO, and on the particular experiment described the uptake of lime was between 11 and 18 lb. per acre per annum, according to the treatment and species of grass. This removal of lime from the soil, as well as the natural loss as calcium bicarbonate in drainage water, leads eventually to a lime-deficient acid soil in which bacterial activity is reduced. As a result a mat of fibrous matter consisting of semi-decayed leaves, stems, and roots, usually begins to form and gradually accumulates until it may be several inches thick. Even on chalk downs where lime is close at hand the accumulation may occur in course of time, and much old grass land in all parts of the country has developed this surface mat. Lime deficiency can be induced artificially as has been done on the Rothamsted Park grass plots or on the older turf plots at St. Ives by using sulphate of ammonia in regular applications. The condition is more difficult to attain on calcareous soils but relatively easy on siliceous or sandy soils.

Much of the turf found on old-established sports grounds, golf courses, park lands and garden lawns is of this acid matted type. Such acid turf contains the desirable grasses (bent and fescue), some Yorkshire fog, scarcely any crested dog's-tail or perennial rye-grass, and very few weeds. It is characterized by low fertility and low *p*H.* The miscellaneous plants which exist, for example heath bedstraw, wood-rush, cat's-ear, and creeping

* *p*H. A scale for measuring acidity. The neutral figure is 7·0. Lower figures (from neutral downwards) indicate progressive degrees of acidity, higher figures (from neutral upwards) indicate progressive degrees of alkalinity.

hawkweed, do not appreciably detract from the turf unless their proportions become very great. Under acid matted conditions worm activity in turf is either eliminated or very much reduced. Further, such turf provides a dry resilient sward during the winter months, though it has the disadvantage of being susceptible to drought and when once dried out re-wetting by rain is often very slow.

With these facts in mind it is not surprising that the inducement of acidity was at one time regarded as essential for good weed-free turf, especially as American experiments had pointed to the fact that weed-free turf could be maintained in such a state by withholding alkaline reacting materials and treating the turf regularly with those leaving an acid residue, such as sulphate of ammonia and ammonium phosphate. Although these tests were not concerned with eradication it was argued that artificial inducement of acidity would lead to the elimination of weeds and coarse grasses. Actually, however, the elimination of coarse grasses is more a function of the cutting factor and their failure to stand up to repeated keen defoliation. Whereas it is quite true that certain weeds can be eliminated by the use of materials tending to leave an acid soil, the induced acidity is only one factor operating against the weeds present and it is not a pre-requisite for eradication. The evidence indicates that acidity is important as far as control of weed invasion is concerned, though indirect effects like iron and aluminium toxicity may be of more importance than acidity as such.

Apart from this aspect it is important to consider the question of maintaining the soil in an acid condition where this state already exists, and many cases are known where matted turf containing excellent grasses but perhaps lacking in vigour and density has been ruined by the destruction or reduction of the acidity through liming or by using basic slag or other material containing lime. The effect of this is shown in a gradual invasion of weed species, such species as daisy, selfheal, dandelion, chickweed, pearlwort, and plantains being the most likely to appear.

Acid matted turf is relatively free from earthworms, but indiscriminate liming of it leads to a rapid increase in numbers and activity, and instances are known where beautiful acid matted turf, clean and dry in winter, has been reduced to a sea of mud as a result of an injudicious application of lime. It is

true that limed turf is more drought-resistant than unlimed turf, but it is much softer and as there is little or no mat there is no "spring" in the turf.

The effects of liming may clearly be seen on many old-established tennis courts where lines of worm casts and weeds coincide with whitening marks; the effect of the whitening persists for a long time.

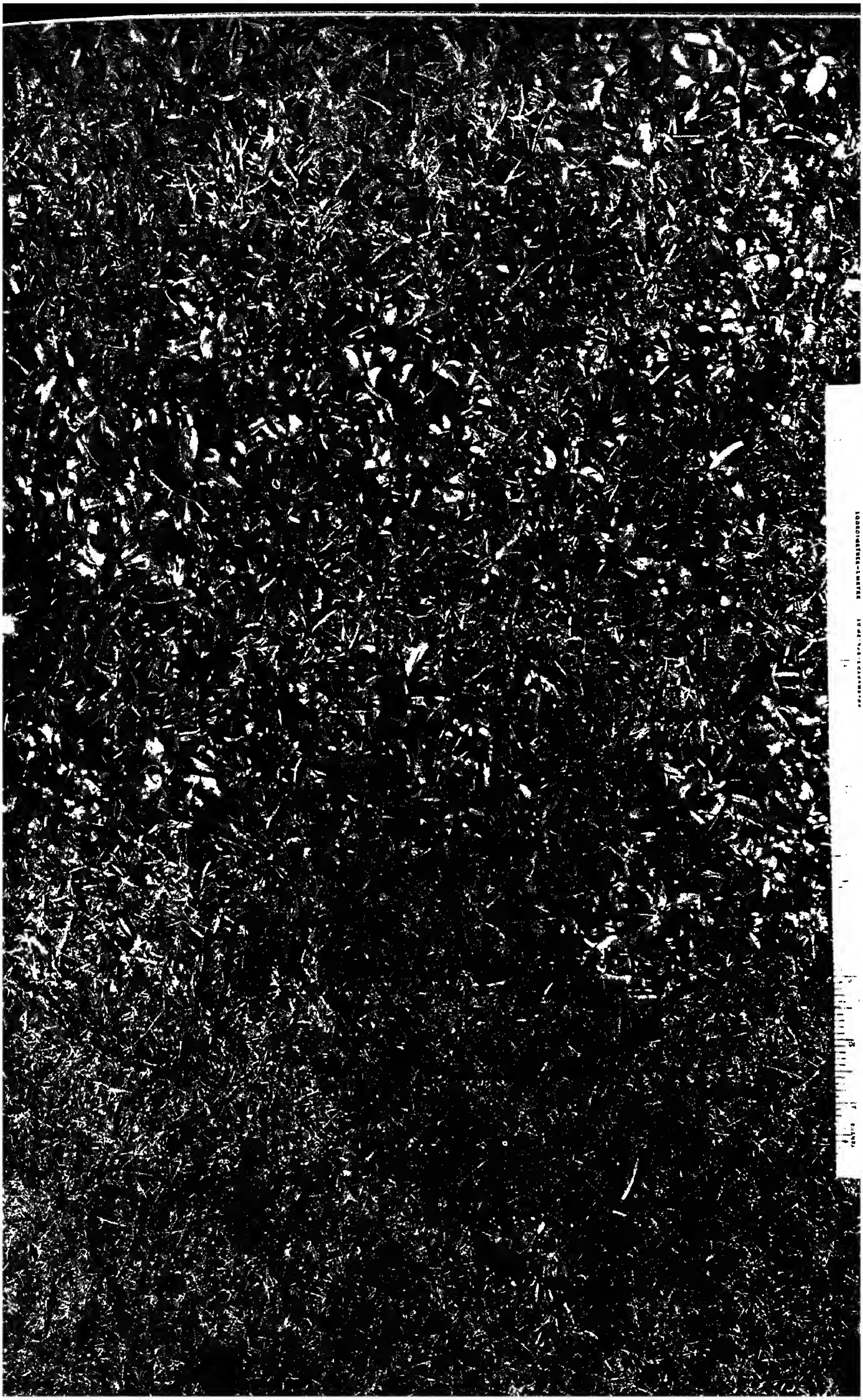
From the above it must not be assumed that lime is always taboo. Liming must only be done judiciously after very careful consideration of the various factors involved. On acid matted turf it is better first of all to try the effects of a general fertilizer containing nitrogen, phosphate, and potash, or a dressing of nitro-chalk at, say, 2 cwt. per acre. If, however, the turf is exceedingly sparse, with wood-rush, moss and sorrel, or highly acid, then it may be that light liming should precede the application of fertilizer. If this is done the rate should not exceed for a start 5 cwt. to the acre (about 2 oz. per sq. yd.) of ground carbonate of lime. In the usual product about 80 per cent should pass through a 100-mesh sieve, though recent work shows that a slightly coarser material serves the purpose. Burnt or quick-lime and hydrated lime are not so suitable, since both scorch the turf, the former rather severely. When there is doubt it is much preferable to take advice on the matter, since an estimation of the "lime requirement" may be carried out in the laboratory. This test determines very empirically the amount of lime required to bring about a condition of neutrality, but in most instances it would appear undesirable to satisfy this requirement completely.

A scientific discussion of the lime status of soils is outside the scope of this book and is a matter requiring further investigation in relation to turf culture. It may well be found that weed and worm inhibition are more directly associated with the amount of exchangeable lime and bases in the soil, or with the toxicity of active iron or aluminium under acid conditions, and only indirectly with the acidity or *p*H. However, the evidence to date points to the advantage of preserving the acid matted turf if naturally present. If it is to be retained, and worm and weed invasion prevented, lime should be withheld except under special circumstances. When the soil is not acid, the attempt to induce acidity may be made by the periodic use of peat, lime-free sand, and good compost, though under

some soil conditions the attainment may prove difficult. It is undesirable to attempt to induce the desirable acid condition by using excessive quantities of quick-acting fertilizers like sulphate of ammonia, while the value of aeration must always be borne in mind under acid conditions when matting is usual.

Systematic use of the hand-fork on small areas or mechanical spiker on large areas of matted turf has, by loosening the soil, aiding water penetration and encouraging root development, often brought about a marked improvement without the use of lime, especially after the mechanical process has been accompanied by suitable dressings of fertiliser.

Fig. 15.—Weed eradication.
Right: Untreated turf. *Left:* Weeds eradicated by sulphate of ammonia and sulphate of iron treatment.



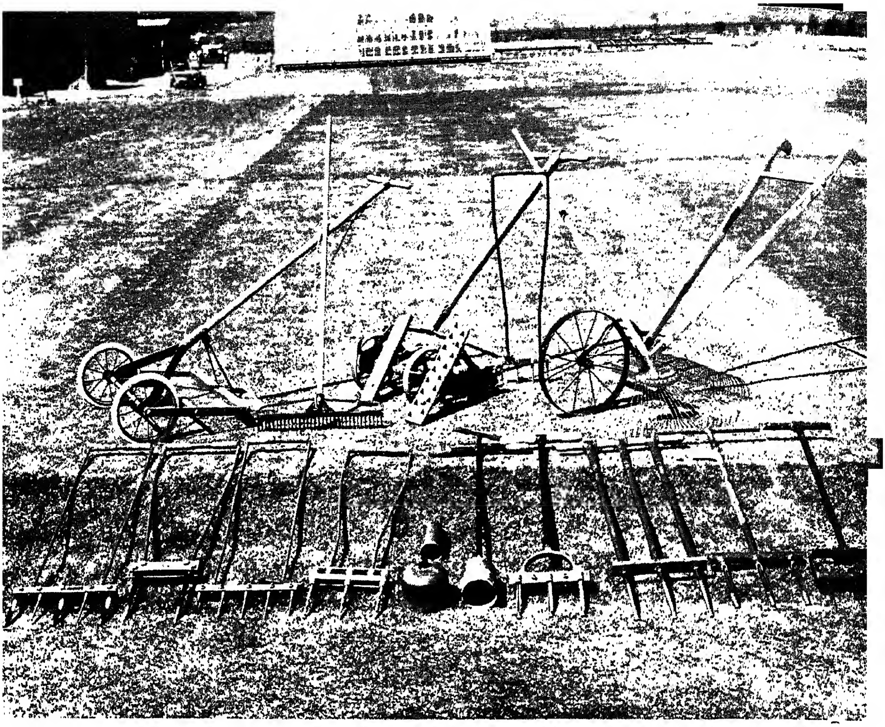
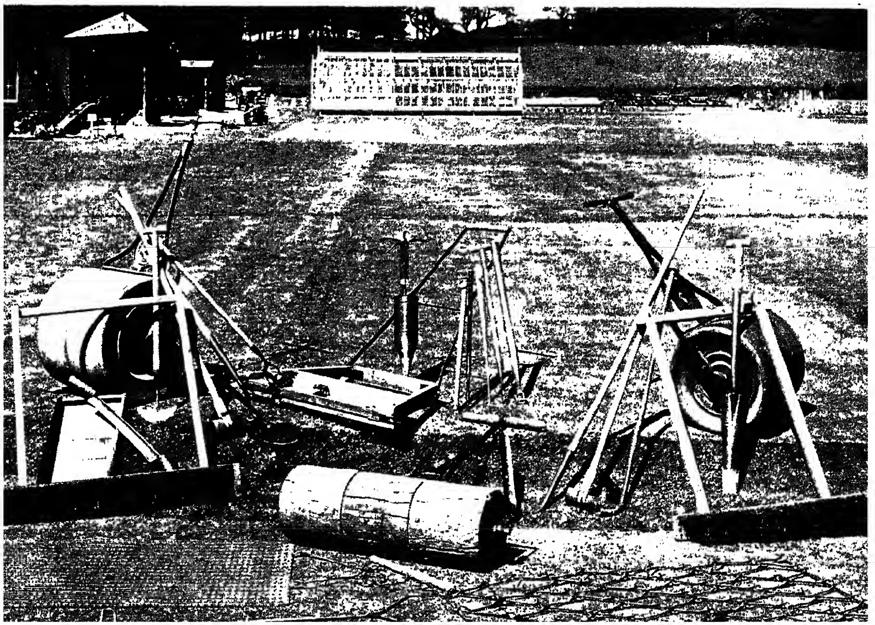


Fig. 16 (*above*).—Forks, rakes, etc.

Fig. 17 (*below*).—General tools, rollers and harrows.



Chapter Twenty

The Weed Problem and Some Common Species

Most lawn owners, gardeners, and greenkeepers are more interested in methods for the eradication of weeds or the control of invasion than in studying the species, their propagation and the reasons for their persistence in turf. Nevertheless, some general knowledge of the factors involved and the species found in turf is a necessary prelude to a study of control. It is not to be wondered that so much interest is taken in weed eradication, since it is a problem that is decidedly acute on many lawns!

In the popular mind a weed is a "plant growing out of place", but no exact definition can be given. Often a weed regarded as an enemy in a lawn is a friend of the farmer, for instance, clover or even ribwort plantain, which sometimes forms a useful plant in sheep pastures. Similarly, rye-grass and cocksfoot, the most valued grasses of the farmer, are regarded as weeds in turf for fine lawns and first-class sports grounds.

Weeds may broadly be classified into three groups, according to the duration of their lives; namely, annuals, biennials and perennials, but at times they merge one into the other. Only a few annuals cause trouble in established turf, though groundsel, chickweed, and fat-hen may appear in newly-sown grass. Since they depend for their continuation upon the setting of seed, such annuals speedily die out under regular mowing. Some annuals, however, like annual meadow-grass and parsley-piert are more persistent, since they are able to adapt themselves to seeding even when the turf is being keenly mown.

A biennial weed is one that requires two years to complete

the life cycle; in the first year germination of the seed and vegetative growth take place, while flowering and seed formation do not occur until the second year. Very few biennials occur in turf, conditions again being against seed formation. Wild carrot and spear thistle are perhaps the exceptions. The vast majority of weeds in turf are perennials having no definite term of existence and capable of constantly spreading and increasing. The most aggressive turf weeds belong to this class.

A list of common weeds of turf and of those less commonly found is given below, and the popular and botanical names have both been included:

Weeds commonly found in turf:

Bulbous buttercup	*Ranunculus bulbosus* L.
Creeping buttercup	*Ranunculus repens* L.
Upright buttercup	*Ranunculus acris* L.
Cat's-ear	*Hypochæris radicata* L.
Creeping soft-grass	*Holcus mollis* L.
Daisy	*Bellis perennis* L.
Dandelion	*Taraxacum officinalis* Web.
Mouse-ear chickweed	*Cerastium vulgatum* L.
Certain mosses	
Pearlwort	*Sagina procumbens* L.
Broad-leaved plantain	*Plantago major* L.
Buck's-horn plantain or starweed	*Plantago coronopus* L.
Hoary-leaved plantain	*Plantago media* L.
Ribwort, ribgrass, or narrow-leaved plantain	*Plantago lanceolata* L.
Selfheal	*Prunella vulgaris* L.
Sheep's sorrel	*Rumex acetosella* L.
Wild white clover	*Trifolium repens* L.
Woodrush	*Luzula campestris* L.
Yarrow or milfoil	*Achillea millefolium* L.
Yorkshire fog	*Holcus lanatus* L.

Weeds less commonly found in turf:

Bird's-foot trefoil	*Lotus corniculatus* L.
Celandine	*Ranunculus ficaria* L.
Chickweed	*Stellaria media* Cyrill.
Cinquefoil	*Potentilla reptans* L
Coltsfoot	*Tussilago farfara* L.
Common erodium	*Erodium cicutarium* L'Her.
Dove's-foot geranium	*Geranium molle* L.
Fat-hen	*Chenopodium album* L.
Field chickweed	*Cerastium arvense* L.
Germander speedwell	*Veronica chamædrys* L.
Heath bedstraw	*Galium saxatile* L.

Hardheads	*Centaurea nigra* L.
Hawk's-beard or smooth crepis	*Crepis virens* L.
Creeping or mouse-ear hawkweed	*Hieracium pilosella* L.
Knotgrass	*Polygonum aviculare* L.
Marsh penny-wort	*Hydrocotyle vulgaris* L.
Musk erodium	*Erodium moschatum* L.
Parsley-piert	*Alchemilla arvensis* Scop.
Ragwort	*Senecio Jacobea* L.
Salad burnet	*Poterium sanguisorba* L.
Sea erodium	*Erodium maritimum* L.
Sea milkwort	*Glaux maritima* L.
Sea pink or sea thrift	*Statice maritima* Mill.
Sea plantain	*Plantago maritima* L.
Shepherd's purse	*Capsella bursa-pastoris* DC.
Silverweed	*Potentilla anserina* L.
Spurrey	*Spergula arvensis* L.
Creeping thistle	*Cirsium arvense* Scop.
Dwarf or stemless thistle	*Carduus acaulis* L.
Tormentil	*Potentilla tormentilla* Leck.
Thyme-leaved speedwell	*Veronica serpyllifolia* L.
Wall or field speedwell	*Veronica arvensis* L.
Water chickweed or blinks	*Montia fontana* L.
Yellow suckling clover	*Trifolium minus* Relb.

In addition to the plants listed above there are various miscellaneous weeds found under the special conditions obtaining on seaside, downland or peaty turf, whilst occasionally garden escapes occur as lawn weeds.

To the lawn owner the chief complaint about weeds in the turf will be the neglected and untidy appearance they impart to the sward, but apart from the æsthetic aspect, weeds affect the neighbouring grasses by competing for room and crowding and shading the grasses from light; they also rob the grasses of soil nutrients and water, so contributing to the progressive deterioration of the turf. Chemical analysis of weeds has shown that they absorb nitrogen, phosphoric acid and potash in relatively large amounts, so that they cause an unnecessary drain on the soil. In dry weather they deplete the water reserves in the soil and thus hasten the onset of drought conditions. The relatively large area of bare ground left when a large weed like a plantain is removed, shows the intense smothering effect of a weed so closely appressed to the ground. Add to this the similar crowding of the underground parts or root stocks of weeds and grasses occupying the same turf, and the great need for checking

weed invasion on turf must be felt to the full. On turf used for sports weeds may prevent accurate play.

On looking through the list of commoner weeds already mentioned it will be realized that most of these species occur in turf in all parts of the country, on every class of soil, and in swards designed for every purpose. They are ubiquitous. The reason for this may be sought in the mowing factor, which constantly operates irrespective of soil, climate, altitude, management, and even manurial treatment. In explaining the spread and general distribution of these common weeds it is important to realize that it is *because* of the intensive mowing that the weed problem in turf assumes such magnitude.

The weeds that survive and become most aggressive in mown turf are those that can, by their habit of growth, not only escape the mower blades but can also, despite cutting, increase either vegetatively or by production of flowers and seeds below the cutting level. Rosette or flat weeds such as daisies, dandelions, the various plantains, and cat's-ear, all grow closely appressed to the ground, so escaping punishment from the mower. Moreover, a single plant occupies a large proportion of ground as compared with a single grass plant in a turf. Daisies, ribwort plantains and cat's-ears, throw out shoots that develop into daughter plants still closely pressed to the ground, so building up the original crown into a closely-packed colony. Under conditions of really keen mowing, e.g. on putting greens, and bowling greens, these weeds do not normally form seeds, but it is a common experience to see daisies flowering and seeding on lawns and golf fairways, and even ribwort plantain seed heads that have escaped decapitation. On seaside turf huge areas of starweed (buck's-horn plantain) are not uncommon, and this is due to the constant mowing and to the weed being able to set quantities of seed well below the level of the keenest cutters.

While the weeds mentioned above are aggressive in turf because of their habit of budding off daughter plants and because of the relatively large size of their leaf blades compared with those of mown grasses, certain other weeds by reason of their habit are still more powerful in the competitive struggle. These are the mat weeds, creeping buttercup, wild white clover, selfheal, yarrow, silverweed, pearlwort and mouse-ear chickweed, to which should be added the gramineous weeds, York-

shire fog and creeping soft-grass. The weeds in this category have the ability to adjust themselves to turf conditions by developing much shortened stems and leaves—thus escaping defoliation—but in addition they can spread rapidly by vegetative means. White clover, creeping buttercup, mouse-ear chickweed and silverweed produce overground runners that force themselves in among the grass shoots, later rooting at the nodes and sending out new shoots. Yarrow, selfheal, and creeping soft-grass increase, however, by a system of underground stems, ramifying in the soil and sending up new shoots.

In addition to the above, certain weeds trail over the surface and do not root at the nodes, e.g. knot-weed, garden chickweed, and various speedwells. Perhaps the worst of the weeds mentioned above is pearlwort, the universal distribution and persistence of which in fine turf is due to its very low moss-like growth, to the fact that it can spread by vegetative growth, and to its capacity also of being able to form seed despite keen mowing. It is therefore a plant singularly well adapted to existence in fine turf.

Not only do weeds directly smother grass but their presence makes the grass grow more upright, less closely appressed to the ground, and consequently it is more seriously defoliated than need be.

Continuous keen mowing of the growing sward and occasional cutting in the winter are essential on putting greens, and keen mowing for at least six months per annum of bowling greens, croquet and tennis lawns. This intensive cutting has a weakening effect on the grass, and when it is accompanied by the continuous ground-floor competition set up by rosette and creeping weeds, leading to smothering or reduced shoot (tiller) production, is it to be wondered that faulty or inadequately managed turf should progressively deteriorate? The removal of ground-floor competition by mechanical, chemical or other means is always the first step to improvement of neglected turf.

The establishment of weeds in turf may take place by two methods—the introduction of seeds, or of portions of the actual plant, and the dispersal may be assisted by a number of factors, such as some fortunate coincidence or the aid of special adaptations of the seed or plant itself. During high winds the seeds of many plants are carried a long distance, and it is not uncommon even for portions of plants like rhizomes to be transported in

this way. Such weeds as dandelion, cat's-ear, groundsel, thistle, and numerous composite plants have seeds equipped with a plume as an aid to wind distribution. The seeds of other plants are provided with hooks that readily catch in the clothing, or in the coats of animals. Birds are known to be active agents in spreading seed, and common turf weeds like ribwort plantain, mouse-ear chickweed, creeping buttercup, dandelion and others, have been found in viable condition in the crops and droppings of many birds. In the construction of new lawns weeds are often introduced by the use of soil transported from elsewhere, as this may contain either dormant weed seeds or lengths of root stocks of such grasses as creeping soft-grass. Small seeds like pearlwort are readily spread by being transported on the feet of human beings or animals, or through adhesion to implements. On areas where the cuttings are allowed to fly, the scattering of daisy heads and plantain seeds usually accounts for their rapid increase. Badly-prepared compost is another source of weed infestation, and the sowing of impure seed may be a cause of much future labour. Improper fallowing of land before sowing is a frequent cause of weed-infested turf, and even if the soil appears to be free from weeds there may still be present, buried in the soil, the seeds of plants capable of establishment in turf, which have been lying dormant for long periods.

Chapter Twenty-one

Weed Inhibition and Weed Eradication

A sharp distinction must be drawn between weed *inhibition*, by which is meant the prevention of invasion into an already weed-free turf, and weed *eradication*, that is the reduction, and final elimination, of weeds well established in the turf. The experiments on this subject carried out by Oakley [38] and others in America, and in this country at the St. Ives Research Station,[39] have shown that pure swards of bent and fescue may be maintained in weed- and worm-free condition by regular dressings of sulphate of ammonia, ammonium phosphate, and ammonium chloride, spread with compost, whilst it has been further shown that dressings of nitrate of soda nitrate of lime, nitro-chalk and lime have the opposite effect. Oakley concluded from his experiments that the ammonium fertilizers prevented weed invasion owing to the fact that they create an acid reaction in the soil.

If a turf has been established from clean seed on a well-prepared seed bed it may be maintained in its weed-free condition by regular light dressings of sulphate of ammonia or ammonium phosphate. On the other hand, dressings of lime and nitrate of soda or sea sand, if given to the new turf, will create the conditions for steady weed invasion. The more obvious reasons for the weed inhibition are the density of turf induced by the nitrogen, the fact that any weed seedlings are rapidly smothered by the new growth, and lastly by the fact that many weed seeds fail to germinate in acid soils.

For those who wish to maintain a new lawn, started, say, in autumn, a good plan is to dress the turf in spring with super-

[38] Oakley, R. A.: *U.S. Golf Assoc.* (*Green Section*), 1925, V, 1.

[39] *Jour. Bd. Green. Res.*, 1933, III, No. 9, 65.

phosphate at 5 to 6 lb. per 100 sq. yd., and to follow with about 4 or even 6 dressings of sulphate of ammonia during the season, applied at 2½ to 3 lb. per 100 sq. yd. with a carrier of compost or sand, or applied in solution. The amount of sulphate of ammonia may be reduced according to the response and should certainly be reduced in the second year. Such treatment may be continued for several seasons before a further application of phosphate, possibly with potash in addition, is necessary, but after several seasons the time may come when very light liming is also required. Mowing must, of course, be carried out regularly and with care, and should a few weeds become established in spite of the treatment they should be pulled out. On older swards that have been cleared of weeds much can be done to prevent renewed weed influx by ensuring that the sward is maintained in dense vigorous condition.

Sulphate of ammonia has been known for a long time as a valuable material in weed eradication, but it is only in recent years that its use has been studied from the critical and quantitative standpoint in an effort to explain how the result is brought about. Experiments [40] have clearly shown that sulphate of ammonia and ammonium phosphate will eradicate such weeds as the following: Wild white clover, creeping buttercup, daisy, selfheal, mouse-ear chickweed, pearlwort, ribwort plantain, sheep's sorrel, yarrow, bird's-foot trefoil, yellow suckling clover and the speedwells. Among these, selfheal and daisy are very susceptible and easy to eradicate, whilst yarrow, creeping buttercup, pearlwort, and mouse-ear chickweed are more resistant to this line of treatment. Further experience and experiments have shown that other weeds than those experimented with above may be eliminated, notably broad-leaved plantain, starweed and cat's-ear, but with these the applications of the sulphate must be heavier or may even require to be given as spot treatment to the crowns of the weeds. Experiments [40] have also shown that the addition of sulphate of iron to sulphate of ammonia gives a more efficient and more rapid reduction, so that it is now usual to apply this chemical in addition to the sulphate of ammonia or ammonium phosphate.

There are several possible explanations as to why weeds are reduced by means of sulphate of ammonia and other acid-reacting fertilizers. It has been suggested that the acidity

[40] *Jour. Bd. Green. Res.*, 1931, II, No. 4, 36, 41.

created is the primary cause and a pre-requisite for eradication, but the eradication of weeds with sulphate of ammonia on limy soil without acidity being induced can be brought about, though re-invasion under these conditions is likely to be more rapid. The fact that very acid turf remains relatively free from the commoner turf weeds suggests that acidity is a contributory factor. Cole [41] and Blackman [42] have suggested that the effect of sulphate of ammonia in eradicating weeds when there is no direct scorching is due to the differential action of the ammonium ions which are toxic to the majority of the weeds while increasing the growth of the grass. Probably, however, several factors play a part in weed eradication by ammonium compounds such as sulphate of ammonia, ammonium phosphate, and ammonium chloride. Thus there is the selective "corrosive" action on the broad-leaved plants, the leaves of which catch and hold more of the fertilizer. Closely-mown grass responds readily to nitrogenous fertilizer, so that there is greater competition against the weed of the newly-developed leaves and roots. Materials like sulphate of ammonia and sulphate of iron have the effect of drying the soil and this may possibly be a factor in eradication and even in preventing invasion.

The Use of Sulphate of Ammonia and Sulphate of Iron. Reference has not yet been made to the quantities of sulphate of ammonia or ammonium phosphate required for weed eradication. Actually, owing to the difficulty of obtaining ammonium phosphate and the higher cost of ammonium chloride it is usual to employ sulphate of ammonia, and a mixture of general use for the control of weeds can be made by mixing together:

3 parts	by weight	sulphate of ammonia
1 part	,,	calcined sulphate of iron
20 parts	,,	lime-free sand or friable compost.

This material may then be used at from 4 to 6 oz. per sq. yd. on 4 to 6 occasions during the growing season. A proprietary mixture having approximately the same proportion of sulphate of ammonia and sulphate of iron may be obtained in granular form. The above mixture and system are particularly effective

[41] Cole, S. W.: *Jour. Bd. Green. Res.*, 1930, I, No. 2, 79.
[42] Blackman, G. E.: *Anns. Appl. Biol.*, 1932, XIX, 204.

in dealing with susceptible weeds like moss, daisy, and selfheal, but where established weeds occur more drastic treatment may be needed. Thus a mixture of:

3 parts sulphate of ammonia
1 part sulphate of iron (calcined)

may be applied neat at 1 oz. per sq. yd., using a suitable distributor to obtain even spreading. For spot dressing of crowns of tap-rooted weeds a "lawn sand" * mixture may be used, consisting of:

35 parts by weight of sulphate of ammonia
15 ,, ,, ,, ,, calcined sulphate of iron
50 ,, ,, ,, ,, dry sand

This mixture may also be used for broadcasting on very weedy turf at 3 to 4 oz. per sq. yd., but it often causes a good deal of disfigurement. If such a mixture is to be stored for any time the addition of about 10 per cent of such drying agents as dried blood, steamed bone flour or castor meal is necessary. Weed killing should always be carried out under dry conditions, and for broadcast treatment when the surface is dewy. The treatment above may be used at any time in the growing season (April to September), but April to June is perhaps the best time because a longer period of the season remains for the recovery and growth of the grass (see Fig. 15).

Mixtures containing the sulphates of ammonia and iron cause temporary blackening, but the nitrogen encourages grass growth. These materials should only be used when the soil is moist and never applied during drought. If drought follows an application artificial watering must be carried out after a few days. A warning must be given regarding the heavy use of the sulphates of ammonia and iron on very acid matted turf, which, especially if dry, will suffer severely and may be slow in responding subsequently.

Like many other matters of turf upkeep, weed killing that assumes large proportions is a subject upon which specialized advice should be taken if the best results are to be obtained without excessive cost and serious damage.

Trials have been made at St. Ives in which nitrogenous fer-

* It may be found more convenient for owners of quite small areas of turf to buy a ready compounded lawn sand.

tilizers with and without sulphate of iron have been compared in their effect on common weeds. The results have not yet been published in detail, but the most outstanding feature of this experiment is that all the plots receiving sulphate of iron in addition to nitrogen contain fewer weeds than those receiving nitrogen alone. It is true that both sulphate of ammonia and ammonium phosphate when used in conjunction with sulphate of iron have had the most pronounced weed-killing effect, but at the same time the weed reduction on the nitrate of soda plus sulphate of iron plots is unmistakable. Even on the dried blood plus sulphate of iron plots, and the nitro-chalk plus sulphate of iron plots weed reduction is quite marked. It would appear, therefore, that most nitrogenous fertilizers when used in conjunction with sulphate of iron tend to encourage grasses at the expense of the weeds.

Sulphate of iron when used alone has weed-killing properties and is particularly useful for the control of moss (see Chapter 22) and small weeds. A common mixture high in sulphate of iron, devised by Dr. Murray in South Africa, consists of:

75	parts	crystalline sulphate of iron
15	,,	sulphate of ammonia
10	,,	sand

fused together, ground and dusted on to the weedy turf at the rate of ½ to 1 oz. per sq. yd. The mixture is particularly effective against moss and dwarf weeds.

Before proceeding to a description of other chemical methods of controlling weeds it may be as well to deal with some specific lawn weeds mainly in relation to eradication with sulphate of ammonia.

Clovers. There are on the market a number of compound fertilizers sold as "anti-clover" mixtures, in which the nitrogen is increased to 11 or 12 per cent by the addition of sulphate of ammonia. These are quite effective. White clover may be eradicated by application of the 3 : 1 : 20 mixture (see p. 151) at 4 to 6 oz. per sq. yd. given at approximately monthly intervals, but it is necessary to supplement this treatment by raking for the purpose of pulling up the runners. On a thin sparse turf the use of a general fertilizer to thicken the turf may also be necessary. The New Zealand Board of Greenkeeping Research advise that if phosphate dressings are not to encourage clovers

they must be given in autumn rather than spring. Blackman[43] attributes the reduction of clover following the use of ammonium compounds to the toxicity of the ammonium ions absorbed by the plant from the soil. On some soils clover is very resistant to treatment with ammonium compounds, and it is therefore often a help in such instances to increase the general fertility of the soil to produce a denser covering of grass. Clover is often associated with patches of turf containing worms, and here deworming should be a preliminary treatment.

With tap-rooted yellow suckling clover, if the number of plants is too great for hand weeding they may be spot treated with pinches of sulphate of ammonia, or eradicated by broadcast treatment with sulphate of ammonia at 1½ to 2 oz. per sq. yd., the treatment necessarily being carried out before the flowering and seeding period.

Plantains. Among the plantains, the broad-leaved species (*P. major*) is the most resistant to treatment. It occurs on wet puddled turf, but may be disposed of by several regular dressings of sulphate of ammonia at 2 oz. per sq. yd., though the scarring may involve renovation with seed. Spot treatment with sulphate of ammonia, or the lawn sand mentioned, on large isolated plantains may also be necessary. Another method is to take out small cores of turf with the weed in the centre and to invert them, placing the roots upwards, but this is more a pastime than a practical method! The hoary-leaved plantain with its long tap-root should be hand lifted, or poisoned by stabbing with an injector. Ribwort plantain responds, unless the plants are very old established, to regular dressings of the 3 : 1 : 20 mixture, but stronger plants must be poisoned, spot treated or hand lifted.

On fine turf under seaside sand dune conditions, starweed is often a very serious weed, at times occurring on inland turf on light land. It is best hand weeded, though good results have been obtained by broadcasting sulphate of ammonia at 2 oz. per sq. yd. or by spot treating larger plants with this chemical in dry form or with arsenic acid solution (see later).

Cat's-ear and Dandelion. Where these are well established the quickest method of eradication is by stabbing with an injector containing poison (see later), or spotting with sulphate of ammonia; alternatively, lawn sand is fairly effective.

[43] Blackman, G. E.: *Anns. Bot.*, 1934, XLVIII, 975.

Mouse-ear Chickweed. This weed often follows the use of sulphate of ammonia, and in fact the fertilizer has been blamed for its spread. Where this has occurred the invasion may be attributed not so much to the sulphate of ammonia but to insufficient or inaccurate use of it. Regular raking before mowing and dressing with the 3 : 1 : 20 mixture or the mixture advised below for pearlwort, should be carried out.

Pearlwort. Perhaps this is the greatest scourge of highly-managed turf, and a great many theories have been advanced for its rapid spread in recent years. Both soil acidity and soil alkalinity have been blamed! On experimental plots at St. Ives it has appeared where nitro-chalk, nitrate of soda and lime have been consistently used, whereas on plots regularly treated with sulphate of ammonia, ammonium phosphate and ammonium chloride, the weed is entirely absent. It seems to be more often associated with annual meadow-grass than with bent and fescue. Height of cut also appears to influence its spread and experimental plots mown keenly contain more of the weed than those mown less keenly. On account of its low-growing habit it is often confused with moss or a fine grass, and it spreads rapidly by low runners that work their way among the shoots. The minute seeds are readily transported on machines and feet, and the plant can flower and seed below the level of the mowing machine blade.

It is often said that pearlwort cannot be killed, but like any other plant it may readily be eradicated by chemical and other treatment. Pearlwort develops so insidiously that unfortunately it is often allowed to develop into large dense patches before steps are taken to deal with it. The difficulty is not that it cannot be killed, but that it is almost impossible to effect a reduction without causing much damage to the turf.

Two general methods of treatment may be adopted. (1) A wet treatment, consisting of $\frac{3}{4}$ oz. sulphate of iron (crystals) and $\frac{1}{4}$ oz. sulphate of ammonia, dissolved in $\frac{1}{2}$ gal. of water, per sq. yd. of turf, at intervals of 2 to 3 weeks. It may be necessary to augment this treatment with a general fertilizer later. (2) A dry method, involving the application of a mixture of 2 parts by weight sulphate of iron (calcined), and 2 or 3 parts by weight of dried blood, applied at the rate of 1 oz. per sq. yd., usually with a carrier. Repetition may prove necessary. Experience of

this method has shown that the subsequent recovery of the grass is aided if the mixture is made up of:

3 parts	by weight	of	sulphate of iron (calcined)
2 ,,	,,	,,	,, sulphate of ammonia
1 part	,,	,,	,, dried blood

used at 1 oz. per sq. yd. with some dry sand as a carrier.

These treatments are all apt to scar the turf, and some degree of renovation with seed may therefore be necessary unless there is sufficient grass present among the patches of pearlwort to ensure speedy recolonization. There is no doubt that lawn owners fail both to treat pearlwort severely enough or promptly enough.

Yorkshire Fog and Creeping Soft-grass. Patches of either of these grasses are often found in fine turf. Where the patches are small they should be removed and new turf inserted before they have time to enlarge, whilst systematic slashing and raking followed by re-seeding will do much to thin out the patches and generally reduce them to smaller proportions.

Other Chemical Methods of Control. Mention has already been made of an implement known as an injector for poisoning weeds. In action this is rather like a large hypodermic syringe that can be filled with liquid weed-killer for stabbing into the heart of the weed. It is useful for applying dilute solutions of poison and covers an area rapidly. There is always a danger, however, that unless used carefully the poison will destroy or retard much of the surrounding grass.

There is also on the market a "gun" that can be filled with dry weed-killing powders such as sulphate of ammonia and releases a given quantity upon the crowns of the weeds. Both implements save much back-bending!

For use in the injector type of weed eradicator a saturated solution of sulphate of ammonia is quite effective and safe to use, and subsequently it gives good recovery of the surrounding grass. A 20 per cent solution of sulphuric acid, ordinary creosote, sodium arsenite weed killers, and solutions of arsenic pentoxide and sodium chlorate can also be used in it.

The use of arsenic pentoxide for spraying weed-ridden turf and for stabbing isolated weeds has been extensively studied in

New Zealand,[44a] and use has been made of the method in this country. When a solution of arsenic pentoxide is made in water, arsenic acid is produced and actually in this country it is easier to purchase the liquid arsenic acid than the solid pentoxide. For spot weed-killing purposes 1 gal. of the commercial arsenic acid (sp. gr. 1·76) may be diluted with 40 gal. of water, and in dry weather stabbed into the crowns of the weeds. The arsenic acid is recommended in New Zealand for all-over spraying on weedy turf; but little experience except of the experimental type has yet been obtained in this country, and the method should not be adopted without first taking advice. The method has the disadvantage that all-over browning takes place and a minimum period of 2 to 3 weeks is required for recovery. The method is not one that should be attempted by the amateur, but it is worth including details in this account.

For weeds like daisy, ribwort plantain, broad-leaved plantain and cat's-ear a 1 in 60 or 1 in 80 solution should be employed. It is applied to both grass and weeds through a knapsack sprayer at 1 gal. of the dilute liquid to 20 sq. yd. of turf. Renovation of the ground freed from weeds is nearly always necessary, and it is advisable only to use the arsenic acid when the soil is moist and in good heart and preferably in the early part of the season. Pre-treatment with equal parts of nitrate of soda and superphosphate at 1 oz. per sq. yd. two weeks before spraying is advised by the New Zealand workers, as a means of inducing a good after-recovery. For weeds like pearlwort and mouse-ear chickweed more dilute solutions, such as 1 in 100 and 1 in 120 may be used, and trials at St. Ives have shown these dilutions to be effective, though the temporary browning of the turf might be unpopular in practice and some renovation is sure to be necessary. Much work with arsenicals has been done in the United States.[44b]

Another poison, of which much has been heard, is sodium chlorate, which should only be used for all-over treatment on pathways. For stabbing individual weeds it may be used as a 10-per-cent solution. Recovery of adjacent grass is apt to be slow as the chlorate is held in the soil. Latterly, solid cones that contain sodium chlorate as a base have been put on the market.

[44a] Bruce Levy, E., and Madden, E. A.: *N.Z. Jour. Agric.*, 1931, **42,** 406.

[44b] Monteith, John, Jr., 1940, *Bull* **27**, *Imperial Bureau of Pastures, Aberystwyth.*

These are pushed into the crowns of the weeds and are very effective, but in the absence of an instrument for inserting the cones, much back-bending is required.

Other materials sometimes used are a copper-sulphate solution (not advised), petrol, and paraffin oil, the latter liquid being painted on to the crowns of rosette weeds with a brush or applied through the injector. Calcium cyanamide, sodium thiocyanate, and common salt are all useful, but there is a lack of comparative experimental data as to relative cost of materials and labour, as well as of efficiency.

Spray trials in the United States and Canada with di-nitro-ortho-cresylate, paraffin and other oils on dandelions and plantains have given promising results and extended work on the same lines is desirable in this country. Mercurated ethyl stearate applied as a 0·1 per cent solution in paraffin oil gave, in American trials, a marked reduction in dandelions.

There is no lack of chemicals capable of killing turf weeds. The difficulty is to choose those having some degree of selectivity, capable of damaging the weed fatally but the surrounding grass only temporarily.

In concluding this account of weed control it must be stated that no single method may be adopted for weed control. Thus, if dressings of sulphate of ammonia are being used it may well be that a few isolated weeds have to be hand lifted, and with creeping weeds raking is a valuable auxiliary to chemical treatment. Hand weeding may never be completely superseded, but large areas are best treated by chemical means.

Fig. 18.—A comparison of two turves. *Left:* From unforked turf. *Right:* Taken from immediately round a fork hole.

Fig. 19.—Showing the development of new roots in a tubular fork hole.

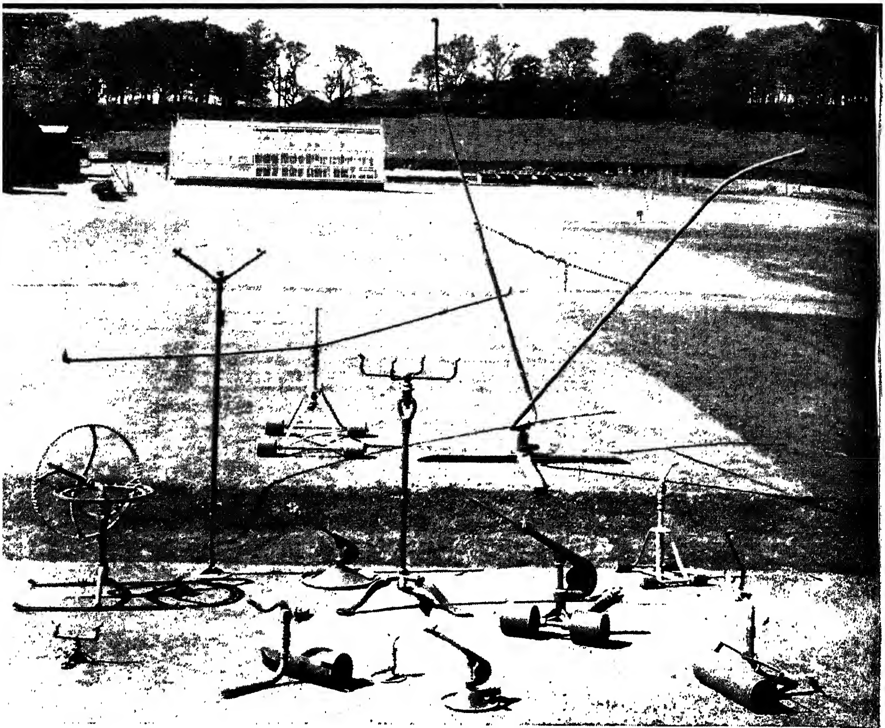
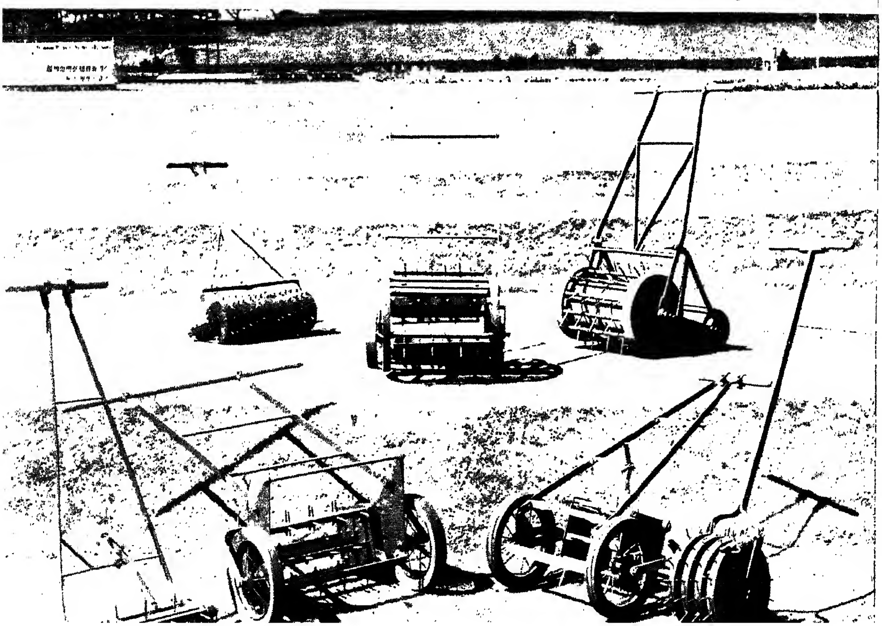


Fig. 20 (*above*).—A selection of sprinklers.

Fig. 21 (*below*).—Pricking and spiking machines.



Chapter Twenty-two

Moss

Perhaps one of the commonest weeds of neglected turf is moss, which name is used promiscuously to cover all species. It is commonest in the autumn and winter months when the growth of grass is least and when atmospheric humidity and soil moisture are naturally greater.

True moss should not be confused with pearlwort, a low-growing plant (p. 155) that superficially resembles it. In Scotland the word "fog" is often applied to moss as known in England, and this term must not therefore be confused by Scottish readers with the term "Yorkshire fog" as applied to species of *Holcus*.

Moss spreads in turf by a variety of methods that are singularly effective in ensuring colonization of new ground. Most species produce small capsules above the leafy part of the plant which contain the dust-like spores so easily dispersed by wind, rain-splash or the action of machines. These spores germinate after alighting on a suitable substratum and throw out a branched filamentous growth of simple structure (the protonema) that is the first stage in the development of the moss plant as we know it. Generally the spore sends out filaments in two directions, one remaining green and creeping along the surface of the ground, whilst the other loses its chlorophyll and forms an underground filament (a rhizoid). These filaments remain one cell in thickness. The protonema develops rapidly and may even form a tangled green felt. Small buds arise from it, developing young shoots of the adult moss plant. The rhizoids perform the same function as roots, absorbing moisture and minerals, and by developing buds or gemmæ give rise to new

aerial stems. Some of the rhizoids may also reappear on the surface to form secondary protonema.

Moss plants have a definite reproductive or sexual phase in their life history, but as it is very inconspicuous it need not be dealt with here. The various means of propagation combine to facilitate the very rapid spread of moss, and under suitable conditions the rapid colonization of turf is hardly to be wondered at in view of the diversity of methods available.

There are many popular views as to the occurrence of moss, but it is safe to say that its presence in turf cannot be attributed to any one factor. Such factors as bad aeration, bad drainage, low fertility, high acidity, and in fact general neglect, may be predisposing causes. Popularly, moss is most often attributed to bad drainage, but it is perhaps true to say that more moss appears in turf on light, well-drained soil than under heavy wet conditions. Neither does high acidity always favour moss since it may often be found under very alkaline conditions. A spongy loose surface on a green or lawn often favours the spread of moss, whilst undulations which are skinned by the mower soon become colonized by it. It often appears on those portions of greens that have worn thin or dried out during the growing season. Another common cause of moss prevalence is insufficient top-soil, often noticeable on lawns and greens that have been constructed from hillsides and where insufficient top-spit has been returned to the surface.

These are some of the factors covering the occurrence of moss, but it is probable that the various species respond in different manners to the varying conditions.

Examination of moss-ridden turf has shown the following species to be of common occurrence:

Barbula convoluta Hedw.
Brachythecium rutabulum B. & S.
Bryum argenteum Hedw.
Ceratodon purpureus Brid.
Eurhynchium prælongum Hook.
Hypnum cupressiforme Hedw.
Polytrichum juniperinum Willd.

In addition the following two species are occasionally found:

Campylopus flexuosus Brid.
Dicranum scoparium spadicium, Boul.

Perhaps the commonest of the above species are *Ceratodon purpureus*, which has a deep velvety-green appearance, and *Hypnum cupressiforme*, which has a yellowish-golden appearance rather like the golden cupressus.

Observations on experimental plots have shown that, contrary to general knowledge, regular or continuous use of alkaline-reacting fertilizers like nitro-chalk, nitrate of soda and nitrate of lime, tends to favour the spread of a moss such as *Ceratodon*, whilst it is unusual to find it in plots receiving regular dressings of ammonium salts. Moss has also been found at times on plots receiving applications of lime and of basic slag. It cannot be said, therefore, that moss is solely favoured by infertility. The type of fertilizers used plays a part. Further, on plots receiving no treatment the moss has steadily increased, and it has been found in greater quantity on plots sown with fescue than on plots sown down with bent. This may be a measure of the relative aggressiveness of the fescue and bent.

Another factor that has been found to influence the spread of moss is the height of cut, and plots mown at $\frac{1}{8}$ in. height have been seriously infested, whilst adjacent plots cut to $\frac{1}{4}$ in. height have so far remained free from it.

In dealing with moss no one specific operation or treatment can be recommended, but its control may best be effected by a variety of operations intelligently applied. Each case must, in fact, be taken on its own merits and dealt with accordingly. As the layman often assumes that moss indicates an acid soil liming is a popular corrective operation. Whilst some temporary improvement may result from this the general effect is to encourage weeds and worms, and it may do relatively little towards permanently controlling the moss. Where it is thought that the presence of moss is due to infertility it is preferable to make a trial with a general fertilizer containing some 10 to 20 per cent of sulphate of iron, or alternatively the sulphate of iron may be given as a separate dressing on one or two occasions at $\frac{1}{4}$ to $\frac{1}{2}$ oz. per sq. yd. with a carrier of sand, followed by general fertilizer. If desired the sulphate of iron may be given in solution. Dressings of superphosphate at 2 oz. per sq. yd. will seriously scorch moss. Under conditions of low fertility the use of a general fertilizer followed by nitrogen dressings is generally sufficient.

Under very acid conditions, light liming may, however, prove

essential, but it is preferable in case of doubt that independent advice should be taken on the matter. Where a hide-bound condition of the turf exists, forking is a necessary prelude to treatment with sulphate of iron and general fertilizer. Under conditions where there is insufficient soil, the only final cure is to lift the turf, cultivate the soil and add more of it and dress with bone meal before re-turfing. Raking out moss and re-seeding is sometimes recommended, but it is a slow process and more often than not leads to very serious scarring of the turf and a poor recovery of the grass. It is necessary also to bear in mind the possibility that drainage of the mossy turf may be required, though, as already pointed out, moss is by no means always an indication of excessive moisture. Often on damp turf tubular forking followed by fertilizer treatment effects a cure. Charcoal is also useful.

Comparatively recently it has been suggested that potassium permanganate is a suitable material for the control of moss, and experiments conducted at St. Ives have been carried out, though the results have not yet been published. It appears, however, that the common types of moss are resistant to permanganate at low rates, but where a dressing of 1 oz. per sq. yd. was given either in solution or dry form with sand, the quantity of living moss was considerably reduced. *Ceratodon* and *Hypnum* responded partially, but *Polytrichum juniperinum* was more resistant. The treatment was not found to be permanent and recovery of the moss commenced in the autumn months. A comparison with sulphate of iron showed that this was as effective at about one-tenth of the cost, although unless supplemented with fertilizer treatment recurrence of the moss also took place in the autumn months.

In view of the difference in cost it would appear that the permanganate is not so useful an eradicant as sulphate of iron, unless future work proves that the permanganate has some other valuable effect in the soil, such as oxidation of organic compounds and the production of nitrate nitrogen for the use of the grass.

Chapter Twenty-three

Mechanical Operations in Turf Upkeep

Until recent years rolling was almost the only mechanical operation given to turf apart from mowing, but nowadays the range of operations is much wider. Mechanical operations on turf may be grouped according to whether they deal with the surface (e.g. rolling, raking, brushing and pricking), or the sub-surface (e.g. forking and spiking). One might perhaps also include mowing in the first group but it has already been dealt with in a previous chapter.

Surface Operations. *Rolling.* That most lawns, greens, and sports grounds suffer from over-rolling is fortunately now being realized more and more, so that the tendency is to reduce the amount of rolling and to open up the ground after its ill effects. Most swards receive sufficient compression from the feet or from the rolling action of the modern roller type of mower, but on little-used turf or where a side-wheel machine is used, some rolling will of course be necessary. On no account should the roller be used when the surface is wet or the grass so thin that the roller rides upon the surface of the soil.

Perhaps the amateur uses his roller mostly for the purpose of removing irregularities, so that he may avoid skinning during cutting. Irregularities, apart from those following bad laying of turf or by churning up of the surface on sports grounds, are usually attributable to the activity of earthworms which during the autumn and winter season throw up casts, so leaving a surface that cannot be properly mown the following spring. The improvement of such a surface is best attained firstly by the removal of the earthworms and then by regular top-dressings to fill up the depressions. In modern practice it is customary

for most of the trueing process to be done by top-dressing to fill up the hollows and not by rolling to compress the lumps. Final light rolling to put a "face" on the turf then follows (see fig. 17).

The amount of rolling given to a turf must be determined largely by the purpose for which the turf is intended. Thus a cricket wicket which requires a true non-resilient surface must be rolled more frequently and heavily than a golf green, where some degree of resiliency is desirable. For most practical purposes on lawns, a 2-cwt. roller is sufficient. For sports grounds rollers of greater weight are used. Where occasional light rolling is necessary (say on seedling turf) a wide wooden roller weighing about 1 cwt. is satisfactory. Not only does over-rolling result in a bad physical condition of the soil but it leads to the formation of a hard caked layer, especially in dry weather and creates conditions more favourable to such weeds as broad-leaved plantain and knot-weed.

Newly-sown turf must never be heavily rolled, or the young plants will be seriously hampered. Rolling should be more frequently carried out on light land than on heavy, and after frosty periods an occasional roll on a dry surface is beneficial in re-consolidating the turf and aiding the start of new growth in the spring. Moderate rolling with due regard to weather and moisture content of the soil is all that is necessary for general lawn purposes.

Raking, Brushing, and Harrowing. The value of raking as a means of renovating matted or neglected turf is well recognized but often forgotten even by those who are most anxious to improve their turf. Where it is very matted, raking the turf is the best preliminary to further treatment, because it pulls out the tangle of dead leaves from around the base of the grass shoots. Raking also fulfils the function of punishing small weeds and pulling out the runners of creeping plants like clover. Providing moss has not become too thickly felted, raking facilitates subsequent operations for control. Often in neglected turf creeping types of grass form a "nap," which can be much reduced by this simple procedure. Raking also assists the entrance of air, moisture, and mineral matters, and enables fertilizer to be utilized more advantageously by the sward.

A garden rake with well sharpened teeth is effective, but there are on the market various patterns of wire rake that are

very valuable for surface treatment. Where raking is to be carried out as a routine operation for checking weeds like chickweed and clover, or preventing the formation of a nap, there is a modified wire rake, supported on wheels with which the operator can vary the pressure of the prongs on the turf. Various moss rakes are also available. Quite an effective tool can be made by driving a row of nails through an old wooden hay rake from which the teeth have been sawn off. A lath screwed down over the nail-heads prevents them being forced out (see Figs. 16 and 17).

Another surface treatment consists of scarifying with brushes containing steel-wire bristles or spring-steel teeth, this operation fulfilling the dual purpose of tearing out decaying organic matter and of brushing up the shoots of the grasses so that they meet the mower and allow a more uniform cut. Various types of implement for this purpose are on the market, some of them having interchangeable brushes while others are designed on the harrow principle.

Drag brushing is an operation of value in producing fine turf, but commonly neglected. It is particularly useful after the turf has been dressed with fine compost, because pulling the drag broom across the turf causes more top-dressing to be left in the hollows than on the humps, so leading to truer conditions. This operation also helps to drag up the shoots of chickweed and similar shallow rooting weeds so that they may receive greater punishment from the mowers.

Coir or steel-link mats are also effective for working in top-dressings and trueing the surface. Under wet conditions, however, a coir mat is inclined to cause "balling" up of the dressing but neither this nor the chain mat are so effective in pulling up low-lying shoots of grasses as the drag broom.

The amount of spike harrowing that can be given to fine turf is strictly limited, although there are excellent small harrows on the market for the purpose. Vigorous harrowing of turf is often not practicable unless it is being broken in from old pasture, but there are machines that are provided with sets of small knives that slit the turf and so let in moisture and fertilizer dressings. By using a tool of this type the mat of fibre is opened up yet retained and there is little interruption in the use of the turf. Machines with knives of this type are also remarkably effective for punishing creeping weeds such as yarrow and

clover, and marked reductions in the amount of these weeds have been noted following their practical use.

Switching. This operation, usually carried out with a 15 to 20 ft. bamboo cane, is very useful in dispelling dew before mowing, in scattering worm casts, and working in dressings, while it is also beneficial in giving partial control of certain turf diseases.

Pricking. Matted or over-consolidated turf also benefits from other forms of surface treatment such as shallow pricking by means of rollers studded with spikes. The commonest type consists of an elm or steel roller into the surface of which spikes from 1 to 1½ in. long have been inserted. They are arranged diagonally around the rollers and are capable of producing a large number of shallow holes. Better penetration is obtained by pushing such an implement than by pulling, but usually the lack of weight coupled with solidity of the turf prevent more than ¼ to ½ in. penetration. By rocking the implement backwards and forwards maximum penetration of the spikes can be obtained, but the hole produced is slit-like and not circular. Such an operation is remarkably effective in rejuvenating neglected turf, and as a preliminary to fertilizer treatment and top-dressing (see Fig. 21).

This operation is also quite effective when artificial watering is necessary, since each hole acts as a small reservoir and aids the penetration of the water.

Whilst pricking in this manner is effective for aerating the immediate surface of the turf it does nothing to affect the sub-surface layers which are often consolidated by excessive rolling or trampling. Deeper penetrating tools must be used for this purpose.

Sub-Surface Operations. *Forking* is best carried out in the autumn and winter months when it is least likely to cause inconvenience, and on golf greens a portion of the surface is left unforked for a time to maintain play. Unfortunately forking is often imperfectly carried out, but more of it could advantageously be done, especially on heavier soils or on greens where a thick mat of fibre has developed. The compressing action of a player's foot on turf is quite considerable, and amounts to approximately 7 lb. per sq. in., which means a pressure of about 1,000 lb. to a square foot and is equivalent to a 4½ cwt.

roller 3 ft. wide making an arc of contact of about 2 in. Forking is one of the best means of relieving such compression. Until recent years when special forks with tapered and collared tines appeared, forking has always been carried out with an ordinary garden fork or a graip fork either by inserting it straight into the soil to the full length of the prongs and drawing it out on the same line, or secondly, by exercising leverage after insertion. Prising up of the turf in this way is at times found beneficial, but is apt to break the roots and leave an uneven surface, especially if the ground is stony. On light or medium soils straight in and out forking is usually sufficient as it breaks up compacted layers or pan, much as sub-soiling in agriculture (see Fig. 16).

In 1919 the late William Paul of Paisley introduced the tubular fork that now bears his name. This implement removes cores of soil and turf, and has been widely adopted in lawn and green upkeep. The fork, though slower to use than a solid one, leaves a wider and more permanent hole, and on heavy soils and matted greens the removal of this core is especially beneficial because it enables top-dressings of more suitable material to be worked in. Tubular forks must be used with care on light sandy soils because there is a tendency for the sides of the hole to collapse before filling has taken place, thus leaving a pitted uneven surface. It should be inserted to a depth of at least 6 in. at 4-in. centres.

Several modifications of the tubular fork have been put on the market, and in one of them the tines revolve, so aiding penetration, whilst in another the tubular tines have been replaced by a set of spiral tines, which remove about a quarter the amount of soil taken out by the tubular fork. Another variation is a fork with bayonet-shaped tines with which a deep pear-shaped slit may be made below the surface, yet leaving only a small slit upon the surface.

Besides relieving consolidation, forking has other important functions, and it has been found to be beneficial in combating drought. Thus in a certain experiment [45] turf forked one year was found to be more drought resistant than an adjacent unforked area the following season when a drought was experienced. The soil on the forked plot in the dry period

[45] A fuller account of the relationship between forking and drought resistance or recovery after drought appears in *Jour. Bd. Green. Res.*, 1934, III, No. 11, 233.

contained 14·6 per cent of moisture, whilst that on the unforked plot contained only 6·6 per cent. The grass on the forked plot was more vigorous and revived at a greater rate when rain fell (see Fig. 18).

Forking is also beneficial in helping rain penetration after drought, and in practice as soon as a period of drought breaks up pricking should be carried out. This is most important where there is a thick mat of fibre. Matted turf is apt to act like a sponge, so preventing water penetrating to the soil below. An unforked turf receiving rain and artificial watering contained 9·8 per cent of moisture, whereas the soil on an adjacent plot that had been tubular forked and that received the same amount of water contained 15·7 per cent of moisture. This turf was much greener in colour. Forking also favours root development, new fibre roots forming around the sides of the hole and running into the lower levels. No doubt this partly accounts for the increased drought resistance of forked turf. Quantitative estimations show that forking also improves the resiliency of turf even though no leverage has been exerted. Preliminary experiments have given no conclusive data that forking influences nitrification or the relative changes of the ammoniacal and nitrate nitrogen in the soil, though future work may reveal some connexion (see Fig. 19).

Spiking. The value of pricking and forking being so generally recognized, it is only natural that engineers and others should endeavour to produce machines capable of carrying out the work with greater ease and higher speed. Hand forking is not only hard work but it is also slow work, and as a result several types of spiking machine have appeared on the market to meet these objections. The difficulty in designing a suitable machine capable of spiking turf to a depth of 4 to 6 in. is that as the machine moves forward the tine in being withdrawn tears the turf, so leaving a slit with a raised lip, instead of a circular more or less vertical hole. Any machine designed on a rotary system has this disadvantage, and although in some instances a slit-shaped hole would not cause any inconvenience, in most circumstances on fine turf it is better that the hole should be circular in section. To surmount this difficulty spiking machines have been evolved with tines fixed to swivelling bars. This enables the tines to strike the turf vertically and to leave the soil on the same path as the machine moves forward. In one of

these machines the penetration is secured by the addition of heavy weights, whilst in another the penetration is achieved by the adoption of a principle that in reality gives a hammer-blow action sufficient to drive the tines into the turf. In effect there is a high penetration-to-weight ratio (see Fig. 21).

No spiking machine for deep penetration is much use in dry weather when the soil is hard or very compressed, and to get over this difficulty the best machines are planned so that they may be fitted with shorter tines until the soil conditions become soft enough to enable longer tines to penetrate. The production of machines to speed up tubular forking has received attention and experimental models exist. The difficulty is that to obtain deep penetration a very heavy machine is necessary. Further, the tendency is for the hollow tines to become choked.

The machines referred to above are all drawn by hand or tractor, but recently there have appeared at least three types of motor-driven machines in which the work of penetrating the turf is carried out mechanically. In one of these, forward motion, a few inches at a time, is given by the operator, whilst the tines, fixed to a weighted plate, are lifted and allowed to fall and penetrate the turf. In a later invention, forward motion is continuous, enabling the weighted tines to penetrate the turf vertically yet leave without any tearing as the machine moves forward. This model spikes about 600 sq. yd. of turf per hour.

In a third machine the tines are in the form of twist drills, which revolve and are driven into the turf at high speeds so giving the same effect as tubular forking. They are capable of penetrating up to 8 or 9 in.

For large areas like golf fairways, football grounds and athletic grounds, spiking machines on the gang principle are now being extensively adopted to relieve consolidation. If drawn by tractor at 10 miles per hour the larger models will spike from 12 to 16 acres per hour.

Chapter Twenty-four

Artificial Watering

It has already been pointed out that some 80 per cent of the weight of grass clippings removed from a lawn consists of water. Not only is soil moisture removed in this manner but there is a constant loss through transpiration by the grass leaves and by direct evaporation from the surface. Losses by evaporation are greater on a thin open turf than when there is a dense thick pile of grass to shade the soil.

Attention to the water needs of lawns and greens is therefore important, and is worthy of greater care than is usually accorded. There are some grasses, like the fescues, which as a result of their in-rolled leaves are remarkably resistant to drought and show a marked capacity for quick recovery, but other grasses are not so resistant and therefore their water needs must be satisfied more quickly. Thus, bent grass being less resistant than fescue requires artificial watering sooner if it is not to become very parched in dry seasons. Annual meadow-grass soon shows discoloration in dry weather.

Turf growing on lime-deficient acid soils is more susceptible to drought than turf on alkaline soils, while swards on thin sandy soils or under very intensively managed conditions, soon require artificial watering in the event of prolonged dry weather. Failure to satisfy this need is often a cause of weed invasion or weed increase.

Many theories exist as to what constitutes the best method and the right conditions for watering. Some people hold the view that watering should only be done early in the morning, others contend that watering should not be done until the evening, whilst a third group prefer it to be done throughout he day. Often it is said that the water used should not be cold but

air-warm, and occasionally it is stated that the turf must always be warm when the water is applied. Ideally no doubt very cold water is less suitable than air-warm water, but it is certainly better than no water at all. Watering in the sun is not usually regarded as the best practice, although no harm appears to result provided the surface is not allowed to dry out and bake in the hot sun.

Most people worry so much about these details and similar ones that they fail to realize the importance of giving sufficient water. Frequently it is found that the water applied has merely penetrated about ¼ in. Such half-hearted attention is apt to lead to the encouragement of moss and pearlwort and to the development of a much-shortened root system. Watering, if it is to be done, must be done adequately, and as a rough guide, a minimum of at least 2 gal., but preferably 3 to 4 gal., should be applied to each square yard whenever the operation is carried out. The frequency of watering will depend, of course, upon the intensity of the drought and the water-retaining capacity of the soil, but it is not uncommon to find that watering is necessary two or three times a week. The aim should be to ensure saturation of the soil to a depth of several inches. Inspection of the turf by removing a wedge with a knife is helpful in deciding whether or not sufficient water has been given. Often there are difficulties in the way of supplying sufficient water owing to inadequate natural supply or to curtailment of local water supplies. In dry weather, under these conditions, it is much preferable that a single thorough saturation be given rather than several very light sprinkles. Adequate watering is of far greater importance than any consideration of its temperature or the time or method of application.

Most of those responsible for turf upkeep delay artificial watering as long as possible in the fervent hope that rain will fall. The sod may therefore be much dried out before the first application. Under these circumstances it is always more difficult to get good penetration and it is always best to commence watering before the effects of drought have become obvious. Again, examination of the soil by cutting out a small section will give a guide as to the soil moisture and when watering should commence.

While poor penetration of artificial water may be due to allowing the soil to dry out, it may also be caused by a bad

mechanical condition of the surface layer. In either event improved entry may be attained by pricking before the watering. This is best done by means of a spiked roller or by stabbing the surface with a sharp fork. Although 2 gal. of water per sq. yd. has been mentioned as a guide it will be wasted unless it reaches the grass roots.

From the above the following general guiding principles in watering may be enumerated:

(1) Water before the effects of drought are obvious.
(2) Assist penetration by pricking.
(3) Water copiously.
(4) Avoid watering in bright sunlight.

As regards the nature or quality of the water best suited for grass, most lawn owners have to take what they can get, but if there is any choice in the matter very hard water should be avoided. Whilst no experimental data exist as to the relative merits of different qualities of water, practical experience indicates that hard water is apt to encourage weeds, like pearlwort, and earthworms. Water with a low degree of hardness (soft water) appears to be preferable.

The method of applying water to turf is in part governed by the source of supply. On small lawns the usual method is by means of a hose or small sprinkler. When using a hose a fine nozzle is necessary, otherwise top-dressings may be swilled away and the surface of the soil may be opened up. Adjustable hose nozzles may be obtained to ensure a finer spray. In deciding upon whether to use a sprinkler or a hose, attention must be directed to the nature of the terrain. On undulating ground or irregular banks, the hose is to be preferred. Where there are regular banks, however, and funds permit, spray lines can be used to deal with the area systematically. As a rule, sprinklers provide a finer spray than the hose jet and are much less expensive in labour since one man can attend to several.

Before purchasing a sprinkler it is as well to ascertain the pressure of water available since each sprinkler is designed for certain pressure limits. For main supplies, inquiry from the local water authorities will elicit the information, or the pressure may be tested by a gauge. When supplies are delivered by pump, the makers will give the information, but when the supply is by gravity from a cistern, the head may be calculated by allowing 1 lb. per sq. in. pressure for each 2 ft. 4 in. of

height above hydrant level. Thus, a cistern 23 ft. above a tap will give a pressure of about 10 lb. per sq. in. whilst 46 ft. will give about 20 lb. These figures make no allowance, however, for pipe friction, which may cause considerable loss in a long run of small-bore pipe or where there are many bends or obstructions. Pipe friction increases with greater speed of flow.

Sprinklers are designed by the manufacturers to give optimum efficiency when working at a certain pressure, and they may be classed as very low (below 12 lb.), low from 12 to 20 lb.), medium (from 20 to 40 lb.) and high (above 40 lb.). Apart from the consideration of pressure, however, it is necessary to decide upon the amount of money available, and to ensure that the sprinkler will fulfil certain requirements. Thus, to be efficient, a sprinkler must be simple to work, it must cover the maximum area with even distribution, it must create a fine spray, and if it is a revolving type, must turn slowly to reduce wear and secure the maximum penetration. Further, a good sprinkler must be capable of being left untended, should be easily transportable, and should not cause ponding by leakage (see Fig. 20).

It is not possible to mention individually the wide range of rotary sprinklers available on the market to-day, but some idea of their capabilities may be derived from the following figures. A rotary sprinkler with wide arms will operate at as low a pressure as 6 lb., spraying a circle of 30 ft. diameter and delivering 130 gal. per hour. A similar sprinkler at 10 lb pressure will water a circle of 45 ft. diameter and deliver rather more than double the above volume of water per hour. At 40 lb. pressure the same sprinkler will cover an 80 ft. diameter circle with 850 gal. per hour; and at 100 lb. it will water a circle of 120 ft. diameter, applying 1,500 to 1,800 gal. per hour.

The method of obtaining revolutions on the arms of the sprinkler is secured either by the back thrust of the water or by the impingement of the jet on a bobbing arm or on a small paddle geared on to the movable jet, all of which methods ensure the rotation of the spray. In one type, the jet impinges on a toothed wheel which is geared in such a way as to ensure that the single or double jets revolve comparatively rapidly.

The prices of sprinklers are very variable. A small type for garden use may be had for as little as 5*s*., whilst other low-priced sprinklers cost 10*s*. 6*d*. up to 20*s*. Higher-priced imple-

ments costing from £3 to £5 have finer jets and water a wider area of turf.

Another type of sprinkler that has received some publicity operates after the manner of a gun. The water is delivered into a pressure cylinder partially filled with air and on reaching a certain pressure the water is released and thrown a considerable distance. At the same time the jet is given a slight turn. With this apparatus an area of about one acre can be watered without moving the "gun".

Most revolving sprinklers, when operating in still air, cover a circular area, which is a disadvantage on a rectangular or square area as the corners may be missed. It is claimed for at least one patent revolving sprinkler that the jet waters in a square.

For rectangular areas spray lines are now commonly used, the jets being set to cover a width of 50 to 60 ft. These lines are made up in lengths, and there are two types, the fixed type in which the jets are inserted in such a way that a wide area is covered (usually the joints between the lengths are flexible so that the line can be arranged as desired), and the rigid type fitted with an oscillator which ensures that the jets shall be thrown backwards and forwards over a half-circle to cover a 60-ft. width. The cost of such spray lines is from 2*s*. 6*d*. to 5*s*. per foot run according to the mounting and length, whilst lengths from 300 to 600 ft. can be arranged. Such lines are very largely adopted on tennis courts either on the ground or permanently fixed to the framework of the surrounding netting. They have also been extensively used on racecourses and in gardens generally.

Another system of sprinkling provides sets of concealed jets below the ground, and these, when the water is turned on, pop up in a telescopic manner and spray the turf.

For those unable to utilize a mains water supply there are many types of portable or stationary pump on the market, and whilst they may be of little interest for the garden lawn they are being extensively adopted by sports and golf clubs when it is desired to provide an independent supply from a stream, pond or well. In drawing from a pond or stream the risk of introducing weed seeds can largely be avoided by keeping the suction vent well below the surface either as a fixture or supported on a raft.

Fig. 22.—Earthworm invasion. *Left:* Plot receiving regular dressings of nitro-chalk, invaded by earthworms. *Right:* Plot receiving sulphate of ammonia at equivalent rate of nitrogen.

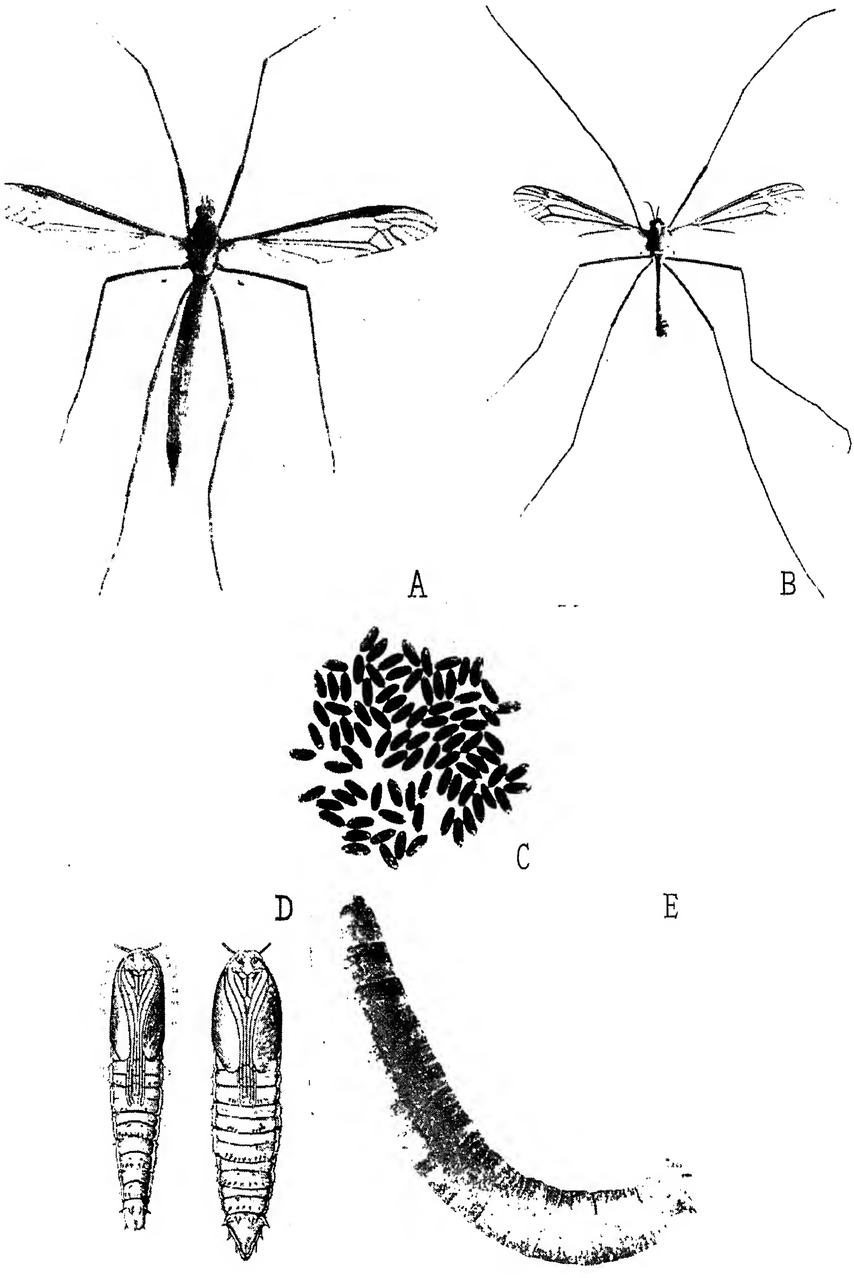


Fig. 23.—Life history of the crane fly (*Tipula* sp.)
(A) Female, 1·3 : 1; (B) male, nat. size; (C) eggs, 3 : 1; (D) pupæ, (*l.*) male and (*r.*) female, 1·3 : 1 (by courtesy of Dr. Kurt Selka); (E) full-grown grub or leather jacket, 2 : 1.

Although many golf clubs and large sports clubs have a running supply of mains water at convenient hydrants it is often the case that use of the water is banned by the local authority during the summer months when rainfall is low and evaporation high, i.e. at just the time it is most needed to ensure a sound and pleasing turf for the holiday season. This state of affairs has led many clubs, considering the installation of running water, to explore the possibilities of permanent pumping stations at nearby ponds or rivers or of artesian wells from which water can be delivered to the hydrants either direct under pressure or by gravity after being pumped to an elevated storage tank. Electrically driven centrifugal pumps have much in their favour for this type of work. The type of scheme to adopt naturally depends on local circumstances, but a number of typical schemes are described, with costs, in the pages of the Journal of the Board of Greenkeeping Research.

With a private plant not only is the recurring cost of the water avoided (usually 1*s.* 6*d.* to 2*s.* per 1000 galls.) but the supply may be used at will for watering, worming, application of fungicides or dissolved fertilizer dressings.

As regards piping, it is usual to employ a ¾-in. rubber hose, but a ½-in. hose is suitable for small supplies. The patent couplings now obtainable are advised as they are instantaneous and save much trouble and inconvenience in dealing with separate lengths of pipe. Interchangeability of unions is, of course, most important.

Chapter Twenty-five

Earthworm Inhibition and Eradication

It is often a firm belief that the earthworm is a desirable, even essential inhabitant of lawns and greens. Whilst no doubt its burrowing activities are valuable in stirring up the soil, providing aeration, improving the surface drainage and reducing consolidation, the habit of voiding the soil swallowed on to the surface as casts introduces a disadvantage that more than counterbalances any benefit. Even if it be conceded that earthworms are beneficial in opening up the soil, one must also concede the fact that present-day intensive management does not call for this help, since it can be provided much more thoroughly and uniformly by mechanical means. The soft squelchy and muddy surface found on turf in the autumn and winter seasons, followed by an uneven surface for mowing, can nearly always be attributed to the earthworm. Besides untrueing the surface of turf, and making it soft and sticky, the "pancaking" of the casts by walking upon them or rolling them down results in a thin open sward in which bent (*Agrostis*) is at a distinct disadvantage as compared with the less desirable species like rye-grass.

Very little detailed information exists as to the habits of earthworms. They normally inhabit heavy moist land and soils rich in organic matter ; they are much fewer and often absent under acid conditions. It is said that breeding takes place mainly in spring and early autumn when high air temperature and humidity, as well as soil moisture, appear to favour activity near the surface. In dry and cold conditions the worms are found deeper in the soil and hence are difficult to expel artificially. Darwin estimated that the earthworm population of an acre of pasture consisted of 53,000 individuals weighing 356 lb.

and capable of moving to the surface 14·58 tons of soil per annum, in the form of casts. In a recent de-worming experiment on infested turf at St. Ives an average yield of 306 worms per 6 sq. yd. was obtained (20 estimations), i.e. 246,800 per acre. The average weight of a single worm in this experiment was 0·7965 gm., giving the total weight of worms per acre as 433 lb. This experiment was done in spring, and when repeated in the autumn on an adjacent area only about one-third the above number of earthworms was extracted. Counts of casts on worm-ridden turf have given an average of 57 casts per square yard (25 counts) over a period of 18 months, with extremes of 22 and 100.

Many lawns show steady annual deterioration through failure to eradicate the earthworm, and the effect of their removal is at once shown in a finer, denser sward with a cleaner surface, and if the sward is used for games, in greater accuracy and uniformity. The elimination of worms from golf greens and fairways has done more towards making the game of golf enjoyable on heavy land in winter than any other factor.

It is usual to find that worm-ridden turf is also weed-ridden, since the bare places left by the casts are resting places for wind-borne seeds of weeds and coarse grasses. Also, worm casts often bring buried weed seeds to the surface.

As with turf weeds, earthworm inhibition and earthworm eradication must be treated as two separate aspects of the same problem, and before discussing earthworm eradication it is necessary to indicate the way in which management has an effect upon earthworm invasion and activity.

Earthworm Inhibition. Recent studies [46] on the influence of management upon earthworm invasion and activity have indicated that mowing, top-dressing, fertilizer and sulphate of iron treatments all have an effect on the re-invasion of worm-free turf and upon activity. Thus mowing trials have shown that the height of cut influences worm invasion. On an area of worm-free turf where 3 different heights of mowing were maintained on separate strips for a number of seasons invasion was greatest on the longest mown plots and least on the shortest; for example, on the average there were 5 casts per sq. yd. where the grass was mown at $\frac{1}{8}$-in. height, as against

[46] *Jour. Bd. Green. Res.*, 1937, V, No. 17, 86.

12 for $\frac{1}{4}$-in. and 15 for $\frac{3}{8}$-in. In further mowing experiments it was found that on an area to which the cuttings were always returned earthworm casts amounted to an average of 15 per sq. yd., whilst on the corresponding area from which the cuttings were always removed in the box the average was 7 casts. In addition, the area to which the cuttings were returned was softer, moister, and contained slightly more organic matter, and presumably this condition favoured earthworm activity. It should be clearly pointed out that the number of casts formed can only be taken as a measure of activity and not necessarily the number of earthworms present, though presumably there is a direct relationship between the two (see Fig. 22).

Observations have indicated that heavy dressings of organic materials like rape meal encourage earthworm activity, and that materials like peat have the opposite effect. Again, dressings containing lime favour invasion. Thus half the area of a weed-free bent lawn was treated once a year with sea sand containing 4·26 per cent of lime in the form of shell, whilst the other half of the area received sharp inland lime-free sand. After a period of four years, during which a total of approximately $5\frac{1}{2}$ oz. of calcium carbonate had been given as shell, per sq. yd., it was found that the number of casts on this area was almost double that on the inland sand plots, average figures being 8 and 4·6 casts per sq. yd. respectively. Again, experimental plots that have received lime show the same phenomenon. For example, the plots receiving sulphate of ammonia periodically and no liming for a number of years had no casts, whilst plots receiving equivalent nitrogen in the form of nitro-chalk (48 per cent $CaCO_3$) the number of casts was 15·4 per sq. yd. ; there was also an increase in weeds. Where plots had been receiving regular applications of sulphate of ammonia with sulphate of iron no casts were found, but plots similarly treated and receiving annual dressings of lime had over 30 worm casts per sq. yd. When superphosphate was given with sulphate of ammonia the worm-free condition was maintained, whilst the addition of lime to the programme of treatment led to earthworm invasion represented by over 30 casts per sq. yd. Nitrate of soda had similar effects.

Other experiments have shown that sulphate of iron used in conjunction with fertilizers that are not favourable to earthworm activity is beneficial in assisting control. Where, however,

nitrogenous fertilizers favourable to earthworm activity were used in conjunction with sulphate of iron the result was to counteract the beneficial effects of the sulphate of iron.

Ammonium salts with or without sulphate of iron have been found not only to prevent invasion but to reduce the numbers of casts on un-wormed turf. Thus counts have shown in one instance 2·7 casts per sq. yd. where sulphate of ammonia and sulphate of iron have been used, against 29·3 where the mixture had not been applied. Sulphate of iron alone also reduced activity on worm-ridden turf. For example 10 oz. of sulphate of iron in small amounts applied over four seasons reduced the range of worm cast counts from 20–40 per sq. yd. to 2–20, whilst an application of 13·5 oz. for the same period reduced the range of casts to 1–4 per sq. yd. The variation is due to differences in the weather conditions between sample dates and the consequent fluctuations in activity. Some of the variation is due to averaging the figures for simplicity.

It may be concluded from the records given above that kind of top-dressing, method of cutting (both in regard to height and the return of the cuttings), and the type of fertilizer treatment influences worm invasion and even worm reduction.

Methods of Earthworm Eradication. The principle involved in earthworm eradication is either to apply a liquid that will penetrate the soil and act as an expellent, or to apply a toxic material that will destroy the earthworms in the soil without necessarily bringing them to the surface. Liquid expellents may or may not also be killers. With liquid materials it is necessary to choose weather conditions that are warm and mild, when the earthworms are working near the surface and the expellent in solution reaches the earthworms by seepage and by flowing down the burrows. Generally, earthworm eradication is carried out in spring or autumn. There are a number of materials commonly used and a description of the methods follows.

Mowrah Meal. Perhaps this material is the most widely used, and it forms the basis of most proprietary worm killers. It is derived from the beans of an Indo-Malay tree, known as *Bassia latifolia,* which are used as a source of oil. The residue after the extraction of the oil contains about 1 per cent of a sapo-glucoside known as mowrin, and it is this compound that confers worm killing properties. The meal is applied in the dry

form to the surface of the turf at from 6 to 8 oz. per sq. yd., and is then copiously watered in. Frothing takes place and the mowrin is dissolved. At least 1 gal. of water to the sq. yd. is necessary but more should be given if possible. It is usually asserted that water applied under pressure is more effective than water applied, say, from a watering-can, but on this point no quantitative data exist. The matter is at present under investigation. The earthworms rapidly come to the surface where the majority die, but it is nevertheless desirable in the interests of tidiness that the bodies should be swept up. Under good worming conditions it is possible to reduce the rate of application of the meal to 4 oz. per sq. yd.

Several grades of mowrah meal are obtainable, some of which are very coarse and contain an appreciable percentage of unextracted fat; these types should be avoided, and only finely ground (superfine) and dry material purchased. In practical large-scale operations it has been found satisfactory to use superfine meal and to apply it in the form of a suspension when the rate can then be reduced to 1½ to 2 oz. per sq. yd., with a consequent saving in cost. Mowrah meal unfortunately does not maintain the turf in worm-free condition for longer than about two years and it is therefore necessary to repeat the application periodically. As regards costs at 6 oz. per yd., a usual cost in material only would be about 2*s.* 8*d.* per 100 sq. yd., whilst on large-scale operations, using the mowrah meal in suspension and applying it through a pump, the cost inclusive of labour comes to between £2 10*s.* and £3 10*s.* per acre. The costings of large-scale worm-killing work at Harborne Golf Club gave a figure, inclusive of purchase of water, labour for applying the meal, sweeping the worms, of £6 11*s.* per acre (2*s.* 9*d.* per 100 sq. yd.), using mowrah meal at 4 oz. per sq. yd.

Mowrah meal does not store well and if allowed to become damp soon loses its properties. It should not be used for de-worming lawns where any of the solution or material is likely to reach fish ponds, as it is toxic to fish.* Mowrah meal contains about 2½ per cent of nitrogen.

* Wild birds disgorge earthworms killed by mowrah meal and it is not advisable to give poultry access to land treated with mowrah meal until a few days have elapsed. No information exists as to the effects on birds of eating earthworms expelled by perchloride of mercury, copper sulphate, permanganate of potash or sodium hypochlorite. Usually after being expelled, the worms are swept up so that if any possibilities of poisoning exist the risk is correspondingly lessened.

Perchloride of Mercury, or Corrosive Sublimate. The usual strength at which this is applied is approximately 1 : 2,500, and in practice 3 oz. are dissolved in 50 gal. of water and applied to about 100 to 120 sq. yd. An application of 50 gal. of water should follow after the dead worms have been swept up. It is highly poisonous, and unfortunately is difficult to dissolve. This latter difficulty may be surmounted, however, by making a strong solution of 8 oz. perchloride and 8 oz. ammonium chloride or common salt in 1 gal. of water; 3 pints of this solution is then sufficient for 50 gal. of water. Taking the perchloride at 5*s.* 6*d.* per lb. the cost of this treatment is about 1*s.* per 100 sq. yd., and it has the advantage of being beneficial in checking fungal disease. Wooden vessels must be used.

Copper Sulphate or Bluestone. The usual strength is 1 : 500, and in practice 1 lb. or 1¼ lb. is dissolved in 50 gal. of water and applied to 100 sq. yd. of turf. Sweeping up should follow quickly, as not all the worms die. At the 1-lb. rate (bluestone costing 32*s.* per cwt), the cost per 100 sq. yd. is approximately 4*d.*, but the material, though not so dangerous to the user as perchloride of mercury, is apt to cause damage to the turf on some soils. The granulated crystals should be used and should be dissolved in wooden vessels.

Potassium Permanganate. This material has been known as a worm expellent for many years but no critical tests to assess its value had been done. In 1937, however, trials carried out at St. Ives* in comparison with mowrah meal showed that results, comparable to mowrah meal at 6 oz. per sq. yd., can be obtained by dissolving ½ oz. in 1 gal. of water, i.e. 1 : 300, and applying it to 1 sq. yd. of turf. Some of the worms die. The cost of using permanganate is approximately 2*s.* 8*d.* per 100 sq. yd., buying at 10*d.* per lb.

Derris. This well-known insecticide was the subject of comparative trials at St. Ives in 1937 against mowrah meal and a combination of it with mowrah meal. Derris, containing 4 per cent rotenone, when used at ½ oz. per sq. yd. and watered in with 1 gall. of water per sq. yd., gave comparable yields of earthworms to mowrah meal. Counts of casts up to 15 months from the date of treatment showed that duration of control was better with derris than with mowrah meal. No enhanced yield of earthworms was found when combining the two materials,

* *Journ. Bd. Green. Res.*, 1938, V, No. 19, 249, 258.

but again where derris was used duration of control was better than with mowrah meal only. Buying derris at 2*s*. per lb. the cost per 100 sq. yd. is approximately 6*s*.

Other Materials. Lime water is sometimes suggested, but cannot be recommended owing to the fact that the lime will naturally favour the further invasion of earthworms. Sodium hypochlorite and mustard and water have also been used. There are, however, no comparative data to show the relative efficiency of such materials, or even of copper sulphate and perchloride of mercury, when used in comparison with a popular worm killer like mowrah meal under identical conditions.

Lead Arsenate. The use of lead arsenate for the control of soil pests has been well established in the United States for a number of years, but it is only in recent years that it has been used at all extensively for the treatment of turf in this country. Lead arsenate has the advantage that it can be applied in the dry form and is therefore most useful where there is no supply of water. It has the disadvantage that it is classed as a poison though it is almost insoluble in water. Various experiments and large-scale trials have been carried out at St. Ives,[47] and these indicate that the rate of application should be 1½ to 2 oz. per sq. yd., the material being best applied at a time when the earthworms are near the surface and active. The material does not damage the grass, though at times a retardation of growth has been observed. At times the lead arsenate is slow to act, but at others quite marked results have been seen in as short a period as 10 or 11 days. Usually it requires a period of 2 to 3 months for any marked control to take place. The earthworms do not come to the surface and from 90 to 95 per cent control, as judged by casts, is usual. Should any casts form on the treated turf they are always very small. Experiments and large-scale trials indicate that the material is usually effective for 5 to 6 years, but cases are known where there has been immunity for upwards of 10 years. The greater initial cost compared with mowrah meal must be offset against the very much longer period of almost complete immunity from cast formation.

Lead arsenate powder is best applied either in neat form through a small lawn distributor or mixed with a bulking agent like coke breeze. It should be left for the rain to wash in. As it is a fine powder, it need hardly be said that it should not be

[47] *Jour. Bd. Green Res.*, 1935, IV, No. 12, 58.

applied in a wind. American experiments have shown that lead arsenate is relatively harmless to poultry, but instances are known in this country in which dead rabbits have been found in proximity to treated turf immediately after application. Although two instances are known of lead arsenate being applied whilst sheep were grazing, without harmful results, it is recommended that stock should be kept off until the material has been washed into the soil by the rain. As lead arsenate has sometimes failed to give results it is desirable at the outset to make trials on a relatively small scale.

It has been suggested, and there is some supporting evidence, that weeds are adversely affected by the use of lead arsenate. Critical experiments are in progress, but no striking differences can yet be reported. The fact of earthworm eradication on a turf means that in all probability there is less chance of weed invasion, since it has been shown that the casts of earthworms often contain seeds of injurious weed species. Experiments at Cornell University [48] have attempted to show that the use of lead arsenate prevented the germination of weed seeds, but the results were negative.

As regards costs, taking the price of lead arsenate powder at £52 per ton, a 2-oz. application would cost £14 1*s.* per acre or 5*s.* 10*d.* per 100 sq. yd. In large-scale work at Harborne Golf Club 1½ oz. was used with satisfactory results at a cost of £10 11*s.* 3*d.* per acre, including the cost of application. This can be compared with the figure £6 11*s.* 6*d.* for mowrah meal, it being realized that longevity of the lead arsenate is at least double that of the mowrah meal.

Colloidal Lead Arsenate. This liquid preparation of lead arsenate was first introduced for the purpose of controlling leaf-eating insects in orchards and the table on p. 184 gives a comparison of the analysis as against powder lead arsenate.

The makers recommend the use of colloidal lead arsenate at 1 pint to 2 gal. of water per 25 sq. yd., which is equivalent to 0·64 oz. per sq. yd. of powder lead arsenate. Carefully controlled comparative trials with colloidal lead arsenate and powder lead arsenate have been carried out at St. Ives (see *Journ. Bd. Green. Res.*, 1938, V, No. 18, 184) and it has been shown, so far as control is concerned, to be immaterial in what

[48] Muenscher, W. C.: *Lead Arsenate Experiments on the Germination of Weed Seeds*, Bull. No. 508, 1930, p. 3. Cornell Univ. Agric. Expt. Station.

Powder	*Per cent*
Calculated on a Dry Matter Basis	
Lead, calculated as PbO	63·87–64·19
Arsenic, calculated as As_2O_5	32·61–32·90
Water-soluble arsenic, as As_2O_5 . . .	00·10–00·15
Fineness through a 300-mesh sieve	97·50–99·24

(=90,000 apertures per sq. in.)

Colloidal	*Per cent*
Moisture .	50·00
Lead, calculated as PbO .	31·50
Arsenic, calculated as As_2O_5	15·50
Water-soluble arsenic, as As_2O_5	00·02

It is claimed that the particles will pass through a hypothetical sieve having 12,000,000 apertures per sq. in. A spreading and wetting agent is added.

(1 pint of colloidal lead arsenate weighs 2 lb.)

form the arsenical is applied provided the requisite quantity of lead arsenate reaches the soil. Using the recommended rate of the colloidal the quantity of lead arsenate applied is but slightly more than that given in a ½-oz. dressing of the powder. Such light dressings of powder have not given control for long periods, although some temporary relief has usually been enjoyed. The trials referred to above failed to support the supposition that the fine particle size of the colloidal is of any advantage or leads to any improved control of earthworm activity. In order that the equivalent of a 2-oz. rate of powder lead arsenate should be given in the colloidal form it is necessary to apply 4 pints to 25 sq. yd. The cost of treating an acre on this basis would be £25 19*s.*=10*s.* 9*d.* per 100 sq. yd., taking the cost of the colloidal lead arsenate as 50*s.* per cwt., whilst the cost of treating with powder lead arsenate at 2 oz. per sq. yd. at 52*s.* per cwt. would be £14 1*s.* per acre, or 5*s.* 10*d* per 100 sq. yd.

Chapter Twenty-six

Insect and Other Pests of Turf

Insect pests of turf are fortunately few, but with one of them, the leather jacket, the damage to turf may be very severe unless its depredations are prevented at an early stage. Most of this chapter will therefore be devoted to the leather jacket, its life history and eradication, but a number of other harmful insects will be referred to later.

Leather Jackets. Nearly everyone must have heard of this grub but only a few realize that it is the larval or grub stage of the long-legged fly known as the crane-fly, or daddy-longlegs. The grubs of all crane-flies are at present grouped together and called leather jackets. No morphological differences are known between the grubs of the various species, but even if they were known they are obviously so minute as to be only distinguishable by specialists.

Damage. The grub may cause damage in all parts of the country, and to food crops as well as to turf. Most instances of turf damage are reported from areas on the sea coast, but there are records of attacks at inland stations also. Perhaps golf courses suffer more than any turf sward, and because of the areas involved, control is proportionately more difficult. Bowling greens and sports grounds generally may suffer, and in epidemics during the last few year's much serious damage has been done to turf swards up and down the country. The grubs feed just below the surface of the ground, devouring roots and basal parts of the stems. As many as 1,000 grubs to the sq. yd. have been obtained, and attacked turf is generally located first by bird activity, and later, especially if drought intervenes, by the dying or serious browning of the overground parts of the

sward. In severe attacks large tufts of damaged turf are loose and can be pulled out by the hands. In mild muggy conditions surface feeding may take place, while in cold conditions the grubs are said to move deeper into the soil.

Life History. The life history of the leather jacket (Fig. 23) has been worked out in greatest detail for the common species known as *Tipula paludosa*. The female fly of this and other species is easily distinguishable from the male by the fatter body and the presence at the end of the abdomen of a pointed ovipositor consisting of two rigid blades between which the eggs are extruded by spasmodic movements of the body; they may even be shot out with some force. They are usually laid by the female as she rests amongst the herbage, though at other times the ovipositor is bored into the soil with a twisting movement and the eggs deposited below the surface. The adults are on the wing from the beginning of August until the end of September and on the average live about 10 days. The eggs are less than 1 mm. in length, are black with a metallic lustre and counts have shown [49] that the average possible number with *Tipula paludosa* lies between 250 and 350, with extreme figures of 48 to 487. In from 11 to 15 days the eggs hatch, the peak of hatching being about the second week in September, though it may vary with the season and district. The grubs at this stage are very minute, delicate and susceptible to drought. Weather conditions in late August and September have therefore an important bearing on the occurrence of epidemics. Mild wet weather is very favourable to them.

By October the grubs are hardier, steadily increase in size, and become more voracious. They feed all through the winter on decaying vegetable matter and living roots until they reach the stage of the familiar legless grey grub. The full size of a well-fed extended grub is 1¼ to 1½ in. long. The grub when fully fed becomes passive in the soil, before the pupal stage, which lasts from 2 to 3 weeks, during which metamorphosis to the adult occurs. Under the right conditions the pupa struggles to the surface, the back of the brown skin splits and the mature insect emerges into the light and dries its wings. The eggs are fully formed in the females and shortly after emergence fertilization takes place and laying commences, the whole process of propagation occupying but a few hours. The crowds of adults

[49] *Jour. Bd. Green. Res.*, 1937, V, No. 16, 12.

often seen in late summer consist in the main of spent adults which are carried hither and thither until destroyed by the elements.

Species. Examination of records shows that at least eight species of crane-fly have been found causing damage to turf or crops of various kinds and a list of them is given below:

Pales flavescens Linn.
maculata Meig.
flavipalpis Meig.
Tipula paludosa Meig.
oleracea Linn.
lateralis Meig.
vernalis Meig.
variipennis Meig.

Sampling experiments [50] have indicated that *T. paludosa* and *T. oleracea* are the most widespread, while of these two *T. paludosa* largely predominates. There is a possibility that *P. maculata* is commoner than breeding-out experiments have shown, and *T. vernalis* has at times been observed in turf. Differences in shape and markings of the eggs of three *Tipulæ*, namely *paludosa*, *oleracea*, and *vernalis*, have been found [50] whilst it seems that *oleracea* lays on the average a greater number of eggs than *paludosa*.

Methods of Control. There are several difficulties in the way of accurately studying methods of control, not the least of these being the habit of migration. Further, infestation of turf is never uniform, and areas may be found that are intensively invaded whereas near-by parts may only be lightly attacked. For example, the outer edges of golf greens are often much more heavily attacked than the more central parts. Many of the erroneous reports published about the control of grubs in turf may be attributed to the failure to realize these differences in numbers, which may lead to a belief that a certain treatment has been more effective than another, whereas the difference is entirely due to a difference in original infestation.

Natural methods of control all play a part in mitigating epidemics. For example, birds eat the adults as well as the grubs. Observations have shown that the grubs are often parasitized by a small fly, *Bucentes geniculata*, the larva of which lives on the tissues of the grub. To what extent this fly controls the pest is

[50] *Jour. Bd. Green. Res.*, 1937, V, No. 17, 107.

not known. Two generations occur in one season. In some experiments on a seaside turf the number of grubs on control plots dropped from 250 per sampling unit to 65 between January 8 and March 3. This may be attributed either to the action of hard frost, cannibalism, or possibly migration.

The observation that adult flies are attracted to light has often prompted the use of light traps. The bulk of adults emerge from the soil by late morning and most of the eggs are laid before midnight. Specimens [51] caught in light traps have been examined and it has been found that only about 5 per cent of the eggs have not been laid by midnight, that is to say 95 per cent have already been deposited before the fly was caught in the trap. In light-trap experiments 62 per cent of the crane-flies caught were *Tipula paludosa*, while only 3 per cent were *T. oleracea*, and it is interesting that in the latter species, the trapped females contained a large number of eggs, perhaps only 5 per cent having been laid. Trapping would therefore appear to be of little use with the commonest species, *T. paludosa*, though it may be helpful with the less frequent *T. oleracea*. Whatever the control treatment adopted it must be of such a nature that it is above all harmless to the turf but effective in either bringing the grubs to the surface or destroying them below. Also, turf that is in good heart will recover rapidly after eradication, just as vigorous turf will be less seriously harmed in the event of an epidemic.

One method of control that has received some publicity is to soak the turf and cover overnight with tarpaulins or rubber mats. The grubs are collected underneath the following morning. The method is not suitable for large areas, and, anyhow, no information exists as to the percentage of grubs removed.

A Paris green and bran mixture has been found effective in agricultural practice, and is a standard recommendation, but the method is open to the objection that it must only be used in mild conditions when the grubs are likely to come to the surface to feed, whilst a second difficulty is the poisonous nature of the Paris green. Naphthalene is sometimes recommended for the treatment of turf containing grubs, but at a rate of application effective in reducing the pest, damage to the turf results. On arable land it is, however, useful. Ammonia solutions have also been tried on turf, and one quart of "880 ammonia" in

[51] *Jour. Bd. Green. Res.*, 1937, V, No. 16, 12.

50 gal. of water applied to 50 sq. yd. is quite effective in bringing the grubs to the surface.

The method that has been most extensively adopted on turf is by means of ortho-dichlorobenzene,[52] which, when emulsified and mixed with a proportion of Jeyes fluid, has given remarkably good results as an expellent. To the knowledge of the St. Ives Research Station over 400 acres of fine turf have been treated with this preparation since 1935. One gallon of the concentrated emulsion is diluted with 400 gal. of water and applied at the rate of 1 gal. per sq. yd. The grubs come to the surface, where they lie comatose and must then be swept up. Provided the soil is moist and the application of the liquid uniform, no harm is caused to the grass.

During recent years much attention has been directed to the use of lead arsenate ($PbHAsO_4$) for the control of leather jackets, and this chemical has been used for controlling various turf pests in the United States and other countries. Extensive experiments [53] have been carried out by the staff of the St. Ives Research Station on affected turf at several centres, using ½ oz., 1 oz., 2 oz. of lead arsenate powder per sq. yd., and 1 pint and 1½ pints of colloidal lead arsenate per 25 sq. yd. From these trials it may be taken as a fact that lead arsenate is effective, but with few exceptions no significant difference was found between ½-oz., 1-oz., and 2-oz. dressings of the powder, but the 1-oz. rate is recommended for practical reasons. Lead arsenate is an expensive material and the question often arises as to whether it should be given as a preventive or only after the attack has commenced. The best plan is to test the suspected turf with the ortho-dichlorobenzene and Jeyes emulsion, and form an opinion as to whether the attack is severe. Thus, if the number of grubs exceeds about 30 per sq. yd., then treatment with lead arsenate may be carried out in November or December. If the grubs are large and well developed their removal with the emulsion is preferable. The powder lead arsenate may be applied neat or bulked with a carrier, either by hand or using a distributor. In the trials there was practically no difference between the effect of ½-oz. powder, 1 pint colloidal, or 1-oz. powder, but cash outlay must be considered. Thus, using 1-oz. powder lead arsenate (52*s.* per cwt.) £7 0*s.* 6*d.*

[52] *Jour. Bd. Green. Res.*, 1932, II, No. 6, 183.
[53] *Jour. Bd. Green. Res.*, 1936, IV, No. 15, 239.

would be spent per acre, whilst for colloidal lead arsenate at 1 pint per 25 sq. yd. at 50*s.* per cwt. treatment of one acre would cost £8 13*s.* 0*d.* The ½-oz. of powder rate involves an expenditure of £3 10*s.* 3*d.* per acre. Observations are still being made in connexion with the longevity of the treatments, but the indications are that it is better to apply ½ oz. of powder each season rather than rely on the 1-oz. and 2-oz. dressings remaining effective for more than one year. When there is any danger from using lead arsenate, such as in gardens or on land to which stock may have access, the ortho-dichlorobenzene and Jeyes fluid should always be used. Also, where lead arsenate treatment has been neglected in the winter, the emulsion may be employed to eradicate the grubs when large enough (early spring) and when their prompt removal is necessary to avoid further damage.

Cockchafer Grubs. In some districts, particularly on light land that is well wooded, epidemics of chafer grubs occur. They do extensive damage by devouring roots of grasses and much secondary damage is caused by birds in their search for grubs. The commonest chafer found in turf in this country appears to be the Garden Chafer (*Phyllopertha horticola* L.). The adult beetles are found in June and so are sometimes called "June beetles", and there is one generation per annum. Very little is known about methods of control in turf but carbon disulphide injected into the soil has been suggested. Paradichlorobenzene has also been advised. Naphthalene may have possibilities, but no critical data exist.

In some attacks powder lead arsenate has been used with encouraging results. It should, however, be realized that the grubs retreat deeper into the soil during winter so that the lead arsenate should only be applied in late summer, early autumn or spring when the grubs are near the surface and likely to be devouring the grass roots. The large cockchafer (*Melolontha melolontha* L.) is at times found in turf. It has a 5 years life cycle.

Dung Beetle Grubs. The grubs of *Aphodius* sp., rather like small chafers in appearance, are sometimes found in turf in the spring. They cause little harm to the turf, but bird action is serious. In recent trials [54] lead arsenate has given control, using 1 oz. per sq. yd.

[54] *Jour. Bd. Green. Res.*, 1937, V, No. 17, 145.

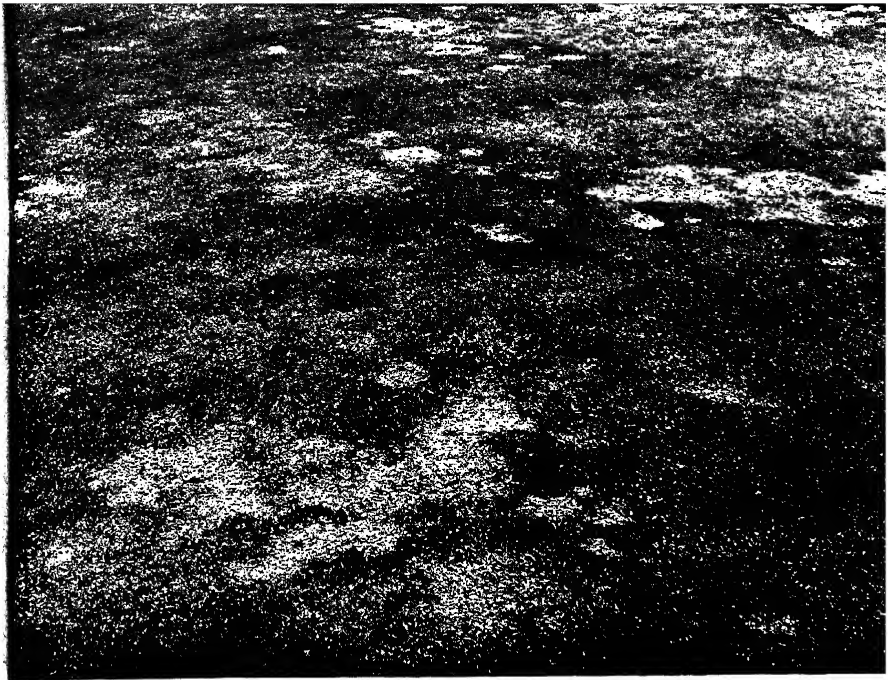


Fig. 24 (*above*).—Fusarium patch disease on mixed browntop and annual meadow-grass turf.

Fig. 25 (*below*).—Dollarspot on fescue.

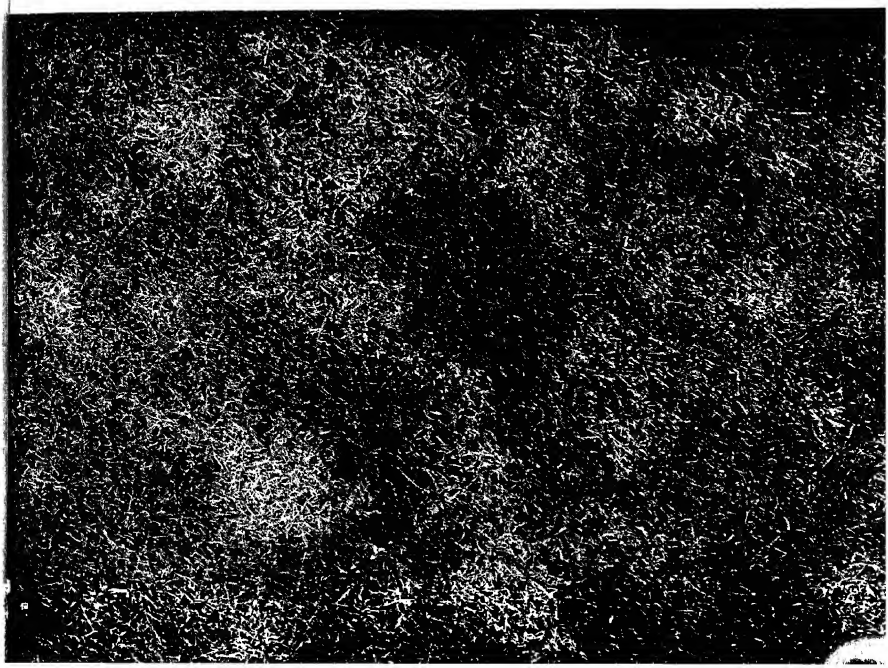
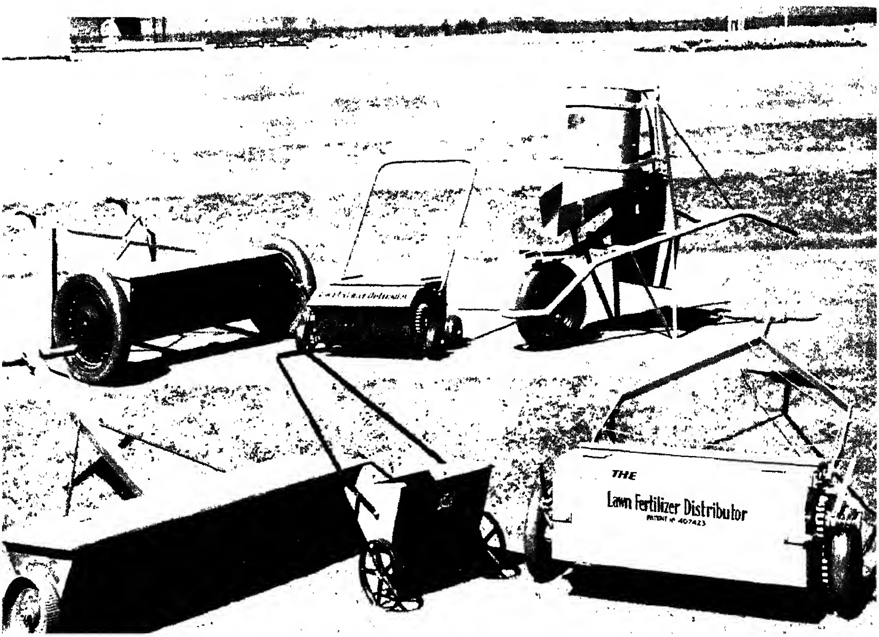


Fig. 26 (*above*).—Fairy ring in park land turf.

Fig. 27 (*below*).—Distributors.



Fever Fly Larvæ. The greyish brown larvæ or grubs of the two winged fly (*Dilophus febrilis* L.) or Fever Fly are sometimes found in turf during the spring or autumn in clusters or nests ¾ in. to 1 in. below the surface. Superficially the grubs resemble small leather jackets for which they are often mistaken, but closer examination shows that unlike leather jackets they have well-developed shining brown heads. The fever fly grubs feed principally on decaying organic matter and are therefore not so harmful as leather jackets, the damage consisting mainly of thin loose patches round the nests or clusters. The life history is described by Lovibond in *Jour. Bd. Green. Res.*, 1938, V, No. 19, 271. Briefly, egg laying takes place in May, and the grubs pupate about the end of August, the adult flies emerging after about one month. The progeny of these flies over-winter as larvæ and emerge as adults the following spring to continue the cycle.

When the patches of grubs are infrequent most greenkeepers will remove them with a hole cutter. Naphthalene has been used, but in a number of instances lead arsenate has been successfully used, either applied broadcast in severe attacks or locally to the clusters. Experiments conducted by Edwards in S. Wales (*Ann. Appl. Biol.*, 1941, 28, No. 1, 34) involved comparisons of 5 materials, namely calomel, ortho-dichlorobenzene, lead arsenate, derris and derris plus pyrethrum and showed almost complete control with lead arsenate at 1½ oz. per sq. yd. In view of experience with lead arsenate against leather jackets it is possible that this rate could be materially reduced.

Ants. At times lawns, especially on sandy soils, are disfigured by ant-hills, which also make mowing difficult. A successful method of control is to inject carbon disulphide into the nests or to introduce a small amount of potassium or calcium cyanide. Where the nests are not conspicuous a poison bait made up with 1 oz. of Paris green to 1 lb. of brown sugar, sprinkled over the ant-infested area, is generally successful.

Other Species. A number of burying beetles are sometimes found in lawns, and throw up small mounds of soil. Apart from this inconvenience, however, they cause no ill effects to the turf. Occasionally in sea-washed turf the beetle *Bledius tricornis*

Herbst. is found. It tunnels into the silty earth and throws up small casts. It does not appear to persist in turf once it has been transferred to inland situations.

In other countries various species occur in turf, such as Japanese and Asiatic beetles in the United States, as well as web worms. Mole crickets and white ants cause trouble in warm climates and the chinch bug is a harmful pest in parts of the American continent. A scarab beetle (*Aphodius tasmeniæ*) has caused damage in S. Australia. The Grass Grub is quite a common pest in New Zealand. Reference will be made to these species when dealing with turf upkeep in other countries.

Chapter Twenty-seven

Fungal Diseases of Turf

he steady rise in the standard of turf requirement in recent years coincides with improved knowledge of turf culture, improved materials and better implements. Improved standards have involved the adoption of very intensive methods of upkeep, and there is consequently a greater tendency for fungal diseases to assert themselves. Fungal diseases of intensively managed turf are not new, though there is little doubt that the artificial conditions under which grass often exists have increased the severity of fungal attack. At the same time, the modern golfer, bowler, and even lawn owner is more fastidious and critical, and there is a demand for turf free from all blemishes. The very fact that greens and fine lawns generally have improved makes small areas of discoloured grass much more noticeable than they would be on a less perfect sward. A discoloured area on a turf is not necessarily indicative of fungal disease, as wear and tear, damage from water-logging, or irregular application of fertilizer may well be responsible, but it often happens that discoloration has originated through fungal attack. Changes in the physiological conditions in which grass is growing, such as an alteration in the state of the soil, in the type of fertilizer used, in water-retaining capacity, and in air humidity and temperature, all affect the internal economy of the grass and may create conditions favourable to disease organisms. Plants in which vitality has been lowered by combination of such factors are more susceptible to attack, but many disease organisms are able to attack healthy plants.

In recent years attention has been drawn to a number of fungal disease of turf in this country, either because they have become more widespread or because more notice is taken of

them in view of the deeper interest now displayed in turf culture. It is proposed to describe these specifically.

Diseases of Newly-sown Turf. Often on recently-sown swards appear brown or reddish-brown areas that may be caused by various types of fungi creating the condition known as "damping off". In some instances the fungus *Pythium* may be responsible, but other fungi, producing similar symptoms, have been discovered. A new species of *Olpidium* [55] has been found in the roots of seedling *Agrostis*, and a fungus known as *Cladochytrium cæspitis* Griffon & Maublanc [56] has also been isolated. It is not known how widespread these fungi are, but newly-sown turf appears to be particularly susceptible to attack by the latter. *Cladochytrium* has been found on *Agrostis* seedlings, but may attack other species and established grasses. Infection takes place through the root by means of a spore that enlarges and sends out a hypa or thread to absorb food materials from the cell. It branches and spreads to the roots and stems of the grasses, the leaves of which assume a reddish hue. Propagation is by resting bodies, and infection takes place from the soil and probably from the seed. No critical method of control with fungicide has yet been worked out, but preliminary tests with sulphate of iron solution and with Cheshunt compound suggest that these might be tried. Cheshunt compound may be used in controlling damping off by *Pythium.*

Diseases of Established Turf. *Fusarium Patch Disease.* This complaint is undoubtedly the commonest and most widespread disease of turf to-day, and it has become on many areas a problem of major importance. The disease is caused by the fungus *Fusarium nivale* (Fr.) Cesati, and is found on all classes of intensively-managed turf, golf greens being particularly susceptible. It must not be inferred that this fungus is a new one, since as a parasite of cereals it has been known for a long time and the winter stage was first described as far back as 1859. It does seem, however, that *F. nivale* is rapidly increasing as a disease-producing organism, and much attention has therefore been focused upon it (see Fig. 24).

[55] Sampson, K.: "A note on a new species of *Olpidium* on the root hairs of *Agrostis*," *Jour. Bd. Green. Res.*, 1933, III, No. 8, 32.

[56] Ivemey-Cook, W. R.: "An account of a disease of lawns caused by a parasite fungus," *Jour. Bd. Green. Res.*, 1937, V, No. 16, 18.

Diseased turf is usually found in September or October, or even during mild periods in winter, when the symptoms appear as unsightly brown patches, often about the size of a penny, but sometimes extending to a foot or more in diameter. Whilst the patches are usually circular in outline they sometimes extend more in one direction than another, and adjacent patches may coalesce until large areas of turf are destroyed. In particularly mild moist conditions a fine cotton-like growth or mycelium appears on the surface, this being white or faintly pink. By placing a specimen suspected of being attacked under a jar indoors for a day or so the cottony growth develops rapidly. Microscopic examination of infected leaves usually discloses the presence of "sickle-shaped" spores.

The activity of the fungus is not always confined to the autumn and winter months, and cases occur from May onwards, but during spring and early summer the grass, which is then growing vigorously, competes strongly and therefore keeps pace with the attack. Autumn infections occur when the vigour of the grass is on the decline. Experience indicates that Fusarium patch disease occurs very largely on annual meadow-grass, but it has also been found on browntop, strains of creeping bent, strains of red fescue, sheep's fescue and perennial rye-grass. Some strains of bent and fescue are more susceptible than others. The fungus over-winters as dark brown aggregates of mycelium embedded in the plant tissues. The spores produced during the active period of growth are dispersed by conveyance on boots, machines and clubs, and by the wind. The fungus spreads along the surface of the leaves, enters through a stomatal opening and then proceeds to penetrate the leaf tissues. Spores are produced on badly-diseased leaves and fallen residues.

Present knowledge of the fungus and methods of control are largely due to Bennett,[57] who was the first to record *F. nivale* as attacking young oats and perennial rye-grass in Britain. Bennett's work has shown that although this fungus has been known for many years on the Continent there is a difference between the Continental strain and the one found in this country. The disease caused by *F. nivale* found on the Continent is known as "Snow Mould", a term that has also

[57] Bennett, F. T.: "Fusarium Patch Disease of Bowling and Golf Greens," *Jour. Bd. Green. Res.*, 1933, III, No. 9, 79.

been applied to the disease in America, but Bennett proposed the name of "Fusarium patch disease" for the British form and it is now generally adopted.[58] The organism grows over a wide temperature and *p*H range, but it has been shown that the optimum temperature for growth is from 68° F. to 70° F. and the optimum *p*H from 6·6 to 6·9. Although the disease sometimes follows a thaw of snow it is by no means exclusively associated with snow in this country.

It is well established that the worst attacks of Fusarium patch disease are related to a weakening of the tissue following very intensive management of the turf or too generous dressing during the late summer, particularly with fertilizers high in soluble nitrogen. Excessive fertilizing and the use of unbalanced dressings are also responsible, and there is evidence that manures rich in soluble phosphate and organic nitrogen are likely to encourage the complaint. It has also been noticed that any treatment that causes a check to the growth, like sanding, has a tendency to favour the disease, whilst experiments have shown that grass which is topped with the mower in winter is less susceptible than that which is left long. Observations and experiments indicate that the acidity of the soil, sometimes blamed for the spread of the disease, is not directly responsible, and that other factors are more potent. Very matted turf is often susceptible and aeration of it is a preliminary to treatment.

In the course of his investigations Bennett found that a solution of an aniline dye, Malachite green, was highly toxic to *F. nivale*, and he devised a treatment involving the use of this and Bordeaux mixture as a sticking agent. Although mercury salts are toxic, their use, on account of their poisonous nature, is not unattended by risk, and hence they are not popular. The malachite green and Bordeaux mixture is readily carried out by first preparing three solutions:

Solution A. Dissolve 18 oz. of fine crystalline copper sulphate in 5 gall. of water contained in a wooden vessel such as a tub.

Solution B. Add slowly 10 gall. of water to 24 oz. of hydrated lime, also contained in a tub. The lime should be mixed to a paste before adding the bulk of water, and then be well stirred.

Solution C. Dissolve ½ oz. of malachite green in 1 gal. of water.

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[58] A full account of this disease, its causes, prevention and cure, was published by the Board of Greenkeeping Research in a bulletin dated June, 1936.

The final solution for spraying on to the turf is made by pouring one gallon of Solution A into a knapsack sprayer through the strainer. Two gallons of the limewater B are then added, this also being poured through the strainer. The contents of the sprayer are then thoroughly shaken and a quart of Solution C finally added. The 16 gal. are sufficient for 750 sq. yd. of turf. For those who do not desire to go to the trouble of making up the material themselves the ready-made mixture can be purchased in powder form.

The material should be sprayed on to the affected turf during dull weather under dry conditions. A knapsack sprayer is preferable, and a penetrating mist essential. Weekly dressings renew the protective coating on leaves and stems, and the spraying should be carried out in spring in March and April in the south and April and May in the north, and during autumn in September and October, especially during muggy weather. The autumn treatment is the more important.

Other practical methods of preventing and controlling attacks are regular switching with a bamboo in the mornings, by aeration of the turf, and by withholding from the fertilizer programme any dressings of a forcing nature or high in organic matter after the end of August. It should be realized that the fungicide stops the attack, but the renewal of the growth on the patches can only take place gradually and in suitable weather. On intensively-managed turf it is preferable that the malachite green and Bordeaux mixture be used as a preventive.

Experiments have been carried out in America and Canada on the control of this disease, known in those countries as "Snow Mould", and the usual recommendation is equal quantities of perchloride of mercury (corrosive sublimate) * and calomel at the rate of 4 oz. per 1,000 sq. ft. of turf. It is necessary to mix the above weight with 30 to 40 lb. of sand as an aid to distribution. In some of the American experiments [59] it was found that continuous treatment with organic nitrogenous fertilizers made the turf more susceptible to the disease, whilst fertilizers such as ammonium sulphate, urea and sodium nitrate

* Perchloride of mercury costs about 5*s*. 6*d*. per lb. and calomel about 7*s*. per lb.

[59] Tyson, J.: *Snow Mould Injury to Bent Grasses*, Bull. No. 19, Mich. Agric. Expt. Station, 1936.

caused less damage. At St. Ives, however, plots treated with nitrate of soda are often seriously attacked. As a result of experiments with varying proportions of calomel and corrosive sublimate Broadfoot [60] in Canada has also recommended the above treatment.

A number of proprietary organic mercury compounds for controlling turf diseases have been put on the market in this country during recent years.

Corticium Disease. This disease occurs in all parts of the country. It is more apt to attack fescues, but bent, annual meadow-grass, rye-grass, creeping soft-grass and some other species are susceptible. It attracts attention by a general pinkish or even red tinge imparted to the herbage, or a pink or red gelatinous growth between the plants. For this reason the disease has received various popular names, such as gelatinous red mould, autumn rust and leaf rust, but these terms may lead to confusion and should be avoided. The main body of the fungus is a thin pink to blood-red layer adhering in small patches to stems and leaves of grasses. The fungus spreads between the grass blades, binding them together, and in humid conditions is quite gelatinous. Spores are produced on the surface of the layer adhering to the plant tissues. In addition the fungus produces pink coral or needle-like outgrowths from near the tips of the dying grass leaves. These consist of matted mycelium and are at first gelatinous, later becoming dry and brittle. They are easily detached from the leaves and are thus easily spread, by wind or on implements or the feet, to other parts so setting up new infection centres. Although dry these "needles" are living and are capable of renewed growth when favourable conditions occur. They withstand extremes of temperature and have grown after being stored two years in a laboratory specimen bottle.

The disease may occur at any time of the growing season but is more prevalent in late summer. Again, this fungus is not a new one, as it was first noted in 1854, and later mycologists gave it the name of *Isaria fuciforme*, and although the name was corrected to *Corticium fuciforme* (Berk.) Wakes. nearly twenty years ago, the old name is still frequently used in catalogues

[60] Broadfoot, W. C.: "Experiments on the Chemical Control of Snow Mould of Turf in Alberta," 1936, *Sci. Agric.*, **16**, 615, and *Jour. Bd. Green. Res.*, 1938, V, No. 18, 182.

and manuals on the management of turf. Bennett,[61] who has also studied this fungus, has found that the optimum temperature for growth is 70° F., a common summer temperature, whilst the indications are that a *p*H of 4·8 to 5·2 is the optimum.

Trials with toxic substances have indicated that malachite green and Bordeaux mixture is also effective for control. The disease occurs on well-managed turf but it is more usual when the sward is low in vigour and has not received appreciable treatment.

Brown Patch Disease. In the United States brown patch disease, caused by the fungus *Rhizoctonia solani*, is a serious problem, as it attacks highly-managed turf under all conditions on large and small areas. Although the fungus has been found in this country it does not appear to be the cause of disease, although further work may indicate that it is more prevalent than is at present realized. In the United States bent turf is very susceptible and temperatures of 80° to 90° F. in humid conditions may cause overnight attack. Precautionary measures entail attention to soil drainage, good air circulation near the turf, to switching of the dew and to avoiding a soft lush growth of grass, whilst as a curative mercury compounds are advised. The usual treatment recommended [62] is 1 part by weight of perchloride of mercury to 2 parts of calomel, 3 oz. being spread with 30 to 40 lb. of dry sand on 1,000 sq. ft. of turf.

Dollarspot. This disease is very common on intensively-managed turf in the United States, and Bennett [63] first found it in Great Britain in 1933. Since then the causal organism has been found on turf from many parts of Britain, though the disease is not nearly so frequent as fusarium patch. The fungus was classified as a *Rhizoctonia* until Bennett's work showed it to be a *Sclerotinia* to which the specific name *homœocarpa* has been added. In Britain dollarspot may be observed at any season of the year, but it is most frequent during mild wet periods in early autumn. The spots are from 1 to 2 in. in diameter and approximately circular, though they sometimes run together to form irregular patches. The optimum temperature for growth of the British strain is 68° to 77° F., whilst in

[61] Bennett, F. T.: "Corticium Disease of Turf," *Jour. Bd. Green. Res.*, 1935, IV, No. 12, 32.

[62] Monteith, John, Jr., and Dahl, A.S., *U. S. Golf Assoc. (Green Section) Bulletin*, 1932, **12**, 87.

[63] Bennett, F. T.: *Ann. Appl. Biol.*, 1937, XXIV, 236.

an American strain studied by Bennett the optimum was 86° F. There is a much higher rate of growth in the American strain than the British (see Fig. 25).

Little information is available as to the control of dollarspot disease on greens in this country but the American recommendation is to use calomel at the rate of 3 oz. per 1,000 sq. ft. with 30 to 40 lb. of dry sand as carrier. Copper and sulphur fungicides are ineffective. The fungus has been found attacking a wide range of grasses, such as creeping bents and fescues, some of which are particularly susceptible. No important differences in the degree of attack can be attributed to alkalinity or acidity.

Root Infections. From time to time the roots of turf grasses are found to be infected with fungal mycelium. Little is known about this condition and its control in practice.

Fairy Rings. Fairy rings are caused by several different fungi that live in the soil. The infestation gradually spreads outward from a central point so as to make an ever-widening circle. Examination generally reveals the mycelium of the fungus ramifying in the soil and weaving amongst the roots of the turf plants. It is generally found at some time of the year that the grass surrounding the outer edge of the ring is stimulated to a deeper green whilst immediately behind this area it may be damaged or even killed. In dry periods this inner zone may suffer severely, since this type of fungus has the effect of waterproofing the soil. In the autumn months under favourable conditions the fungus throws up its fruiting structures in the form of toadstools, mushrooms or puff balls, according to the species involved. Perhaps the commonest species responsible for fairy rings in turf is *Marasmius oreades* Fr., but species of *Lycoperdon* and *Agaricus* are also found (see Fig. 26).

No critical work has yet been carried out on the control of fairy rings, which may at times result in a very unsightly turf. Sulphate of iron has been recommended, a solution being poured down holes made in the ring and a New Zealand suggestion is to use formalin. The present practice of taking out infected soil, replacing it with clean soil and laying new turf over the surface is perhaps the best one to carry out until more is known about control measures.

Shaggy Caps. Although it does not form a fairy ring it is convenient to refer here to the shaggy cap fungus *Coprinus comatus*

Fr. It may cause considerable inconvenience on land that has been made up by tippings and then grassed down. The fungus, encouraged by the warmth of the fermenting organic matter in the tippings, throws up in late autumn eruptions of the caps, which disturb the surface. These caps later decompose into a black objectionable inky mass. No method of control is yet known, but the phenomenon is quite common in industrial areas where tipping is carried out and so is mentioned here.

Other Growths. In concluding this chapter it is convenient to include a number of non-fungal growths found in turf. A very common growth in old neglected lawns is the lichen *Peltigera canina* L., found as brown over-lapping leafy structures. Control is best effected by general improvement of the fertility, i.e. light liming fallowed by a compound fertilizer.

On water-logged turf or turf that is inclined to retain moisture on the surface through sealing up by heavy rolling, gelatinous growths of a blue-green alga (*Nostoc* sp.) may occur. Little is known about their control, but watering with dilute sulphate of iron has been practised with some degree of success. Aeration should be carried out.

Chapter Twenty-eight

Eradication of Vermin

he damage caused to turf by the action of rabbits, moles, field mice and certain birds is sometimes serious, so that it is desirable that methods of control should be considered here.

Moles. Apart from the habit of throwing up mounds of earth, the surface may be upset through the collapse of the burrows. Very often in making shallow surface burrows the mole will push up a ridge of soil, so doing a lot of harm, especially on newly-sown ground. The methods of exterminating moles may be grouped under three headings, namely, trapping, poisoning by baits and gassing. Of these methods the first is best done by professional mole catchers, but poisoning can be carried out by the amateur. The most widely advocated method of destroying moles was until recently by means of earthworms dipped in strychnine solution but under the new poisons regulations this material can only be obtained for medicinal purposes.

Of the various materials tried in the preparation of poison baits, red squill is the easiest and safest to use, and it is obtainable as a powder, liquid or paste from pharmaceutical chemists. Baits made with earthworms dusted with one-tenth their weight of red squill powder are successful if carefully inserted into the runs. There is little danger of domestic animals being harmed.

Two methods of gassing may be mentioned, the first being by means of various cyanogenetic compounds, and the other by means of exhaust gas. Various proprietary dusts, including "Cymag", "Cyanogas", and "Calcid" are on the market for this purpose and in contact with moist soil they evolve prussic acid (hydrocyanic acid) gas. The dusts are blown into the runs

by a blower, of which various types are available. When dust is seen to emerge from holes some distance ahead the first hole is blocked and the blower inserted at the second point and so on until the whole area is treated. It is a simple process and remarkably effective.

Exhaust gas from internal combustion engines has been successfully used, though it presupposes accessibility. There are also certain compound sulphur gases and compounds liberating phosgene. The best times for fumigation are 8 a.m., 12 noon, and 4 p.m., when feeding and tunnelling mostly occur.

Rabbits. The fecundity of the rabbit is so well known that it need not be stressed here. If rabbits are numerous they may cause much inconvenience through scratching and reducing the productivity of the turf, though in their defence it must be said that in their grazing they select principally the clovers and rye-grasses, leaving the finer and less palatable grasses relatively unharmed. In recent years the rabbit pest has become more serious, a fact variously attributed to the low price of carcasses, weather conditions and the use of the common steel or gin trap employed by most trappers. The weight of evidence is in support of the last view since observations on rabbit populations have shown a steady increase in numbers on areas where the gin is used. This is due to trappers, in self-preservation, always leaving some for breeding, whilst there is considerable accidental destruction of the natural enemies of the rabbit.

Apart from snaring, netting, and shooting, fumigation affords a method easy of operation where warrens exist, and it is recommended as being the most humane and effective. The dusts sold for the purpose (see under Moles) are projected into the burrows by means of hand or foot blowers; two men are necessary, one blowing and the other filling in the openings of burrows where the powder is seen to emerge. After completion the main entrances are also blocked. Exhaust gases from car or tractor can also be used, a hose being employed to convey the fumes from the exhaust pipe to the burrow.

Rats and Field Mice. For rats, red squill paste and phosphorus pastes, as well as gassing with prussic acid, are effective. Various virus preparations are also largely used to-day. Whilst red squill pastes may be home-made, it is easier for most pur-

poses to obtain them ready prepared. For field mice, which sometimes cause trouble in turf banks and by burrowing into field drains, red squill paste applied on bread has been found effective, as well as gassing.

Birds. The two species of birds that pay most attention to turf are the starling and the rook. The starling, in searching for grubs like leather jackets, punctures the turf with its beak, and as it is beneficial in reducing grubs it should not be harmed. The rook with its larger beak and habit of using its claws often tears up large areas of turf in search of food, usually cockchafer grubs, and dung beetles, but the grubs of leather jackets are the main cause of the search. The usual methods of shooting, scare-crows and hanging up a dead bird, may be tried, but often the simplest method is to eradicate the soil pests to which the birds are attracted. Sometimes new sown soil is disturbed by sparrows dusting in the loose surface.

Chapter Twenty-nine

Turf Growing under Trees and in Difficult Situations

In the course of this book many general directions for treatment have been given, but it is impossible to lay down instructions for all eventualities and conditions. Certain special cases are dealt with below, but where unusual circumstances occur it is again stressed that technical advice should be taken.

Turf under Trees. A lawn ornamented with trees upon which the sward is continuous below the branches and extending up to the bole or trunk, is most attractive. It is difficult to accomplish this in practice because of the poverty, shade, dryness in summer, and the repeated dripping from rain water collected on the branches during wet weather. The latter is a serious problem in industrial areas or on the edge of towns where the rain is charged with varying amounts of chlorides, sulphates, mineral acids, and suspended matter. The shade factor itself is important, since if deep it deprives the grass of much of the necessary light; to take an example, maintenance of a good sward under the dense foliage of a beech tree is wellnigh impossible. The first operation in endeavouring to create or improve turf below trees is judiciously to lop them, yet carefully preserving their shape.

It is always desirable under trees to leave the grass rather longer than in the open, and periodically to sweep it clear of leaves, conifer needles, branches, twigs, and other débris. Moss is often common under trees and should be kept down by occasional raking, and renovation with seed may be necessary from time to time. Conditions of poverty must be avoided by occa-

sional light fertilizer dressings, and light liming may be needed. The water requirement of the tree and the umbrella effect of the branches may result in serious surface-moisture deficiency for the grass and so occasional artificial watering may be required if the turf is to survive. In some instances it is necessary to renew the turf almost annually beneath trees, and re-turfing is better on the whole than re-seeding. Certain grass species are much more tolerant of shade conditions than others, and amongst these are notably rough-stalked meadow-grass and wood meadow-grass. They should therefore be included in seeds mixtures for these conditions, in conjunction of course with the finer fescues and bents.

Lawns in Towns and Cities. The attempt is often made to produce grass swards in the centre of cities, and whilst tolerable results may be obtained during the summer, the shade of buildings during the winter is often so continuous owing to the angle of the sun that the grass gradually deteriorates. Apart from the deep shade from buildings, however, atmospheric pollution is usually severe, and although high acidity created in the soil may be corrected by liming no way is known of preventing the harmful atmosphere affecting the grass through the leaves—the assimilating organs of the plant. Where grass has to be grown in the centre of cities it is usually necessary to renovate it annually since winter kill is so severe. Late autumn sowings should, of course, be avoided.

Moorland Soils. Under conditions of very high soil acidity the establishment of grass from seed may be inhibited, and although this problem may not occur often on lawns, it is nevertheless quite frequent on golf courses, since they are often constructed on land that is more or less agriculturally derelict. Experiments [64] have shown that light liming is sufficient to establish the common bents and fescues even when this is not sufficient to satisfy the full lime-requirement of the soil. Wavy Hair-grass (*Aira flexuosa*), which is naturally tolerant of acid soils, will establish without this assistance. The use of phosphate on such soils is also important. There is often a tendency for heather to encroach subsequently into established turf. This may be checked by very occasional liming and by fertilizer treatment to encourage a denser turf.

[64] *Jour. Min. Agric.*, March, 1930–31, XXXVII, 1189.

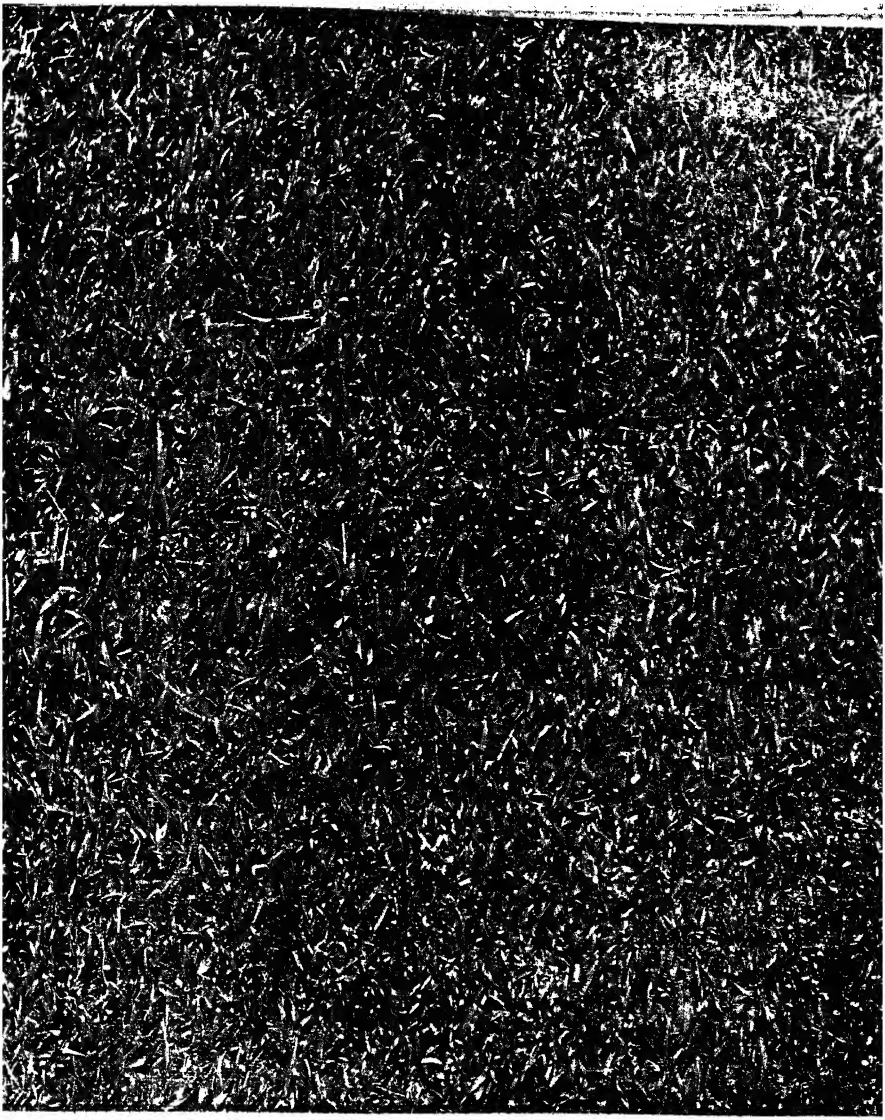


Fig. 28.—Established turf: Browntop.

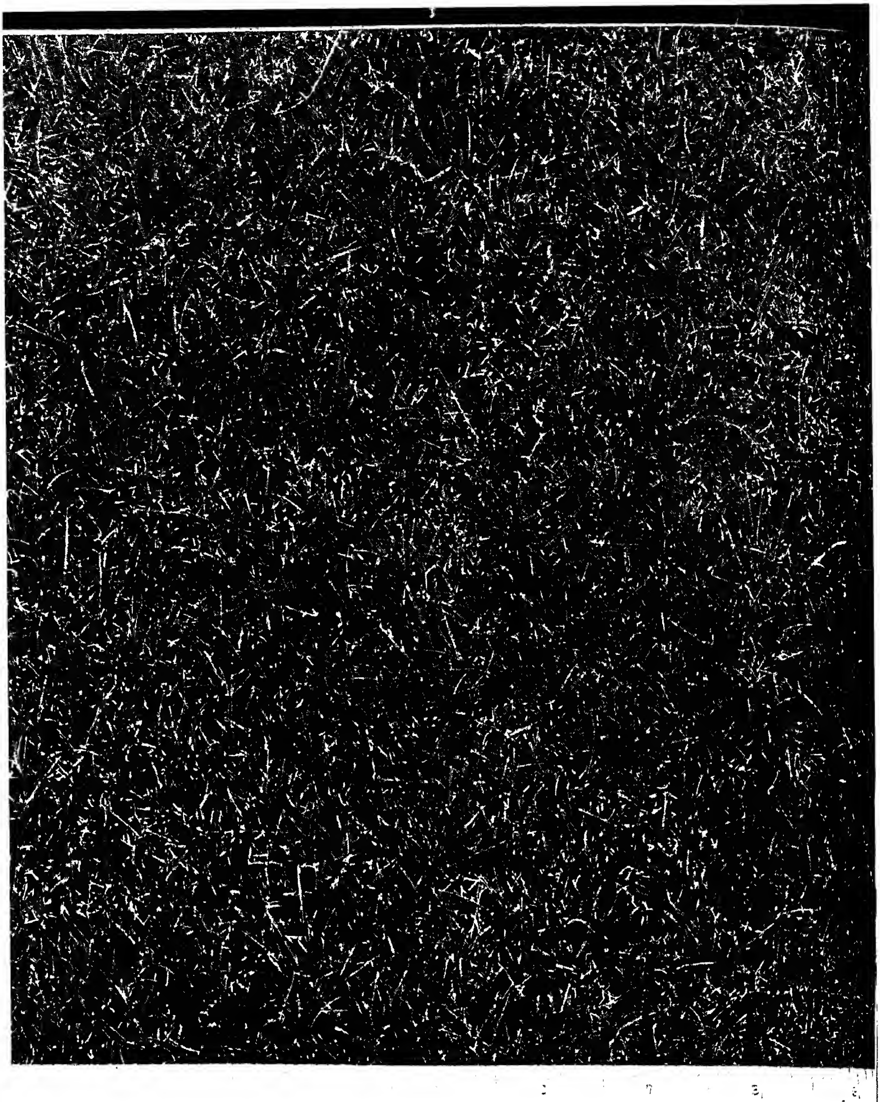


Fig. 29.—Established turf: Chewing's fescue.

Sandy Soils. The establishment of grasses on sandy soils, derived from sand dunes or alluvial deposits, requires great care, since moisture is often deficient. There are indications that spring sowing is more satisfactory than autumn sowing, but the main requirement is to ensure an adequacy of water. In the preparation of a seed bed it is necessary to pay particular attention to the incorporation of organic matter and to use seeds mixtures containing high percentages of fescue. Sodding on sandy soils is successful provided it is carried out in the earlier part of the winter and bone-meal dressings below the sods assist root development. Sandy soils are often acid soils (unless very close to the sea) and this factor should be borne in mind in relation to liming when establishing new grass from seed.

Verges and Slopes. The verges and slopes in a garden should receive similar treatment to the rest of the area. The difficulty on slopes very often is that they dry out in the summer weather and fail to recover before moss invasion commences. They also become poverty stricken, so that fertilizer treatment is necessary. The failure of water to penetrate on banks can be largely overcome by forking. In some instances clay and stones are left near the surface, so making maintenance difficult. The best improvement is then brought about by re-laying and incorporating better soil. Slopes are difficult to maintain when steep. They should therefore be as "gentle" as possible.

Narrow 9-in. to 1-ft. verges give an air of poverty and they are difficult to manage. A more pleasing effect can be obtained if the verge is at least 2 ft. and preferably 3 ft. broad. It should be carefully levelled and always mown with a roller mower. Creeping bent should not be used for verge making. The subject of verges is dealt with on page 86.

Chapter Thirty

The Renovation of Neglected Lawns

Much has already been said about the general treatment of lawns, but it may be helpful to bring together here all the points concerning the improvement of neglected turf. In dealing with the subject it is rather difficult to find a starting point, because the steps to be taken depend so much upon the symptoms and upon the individual case. For example, the condition of the turf may be due to having made a bad start, to lack of attention, failure to realize the amount of work necessary to produce good turf, and to spasmodic efforts of upkeep. Signs of a wrong start may be sought in insufficient soil; subsoil near the surface, and water-logging—which may be shown by the nature of the weeds and by the presence of the wrong types of grasses for producing a permanent sward. Even if a good start has been made it may be followed by neglect resulting in weed and moss invasion, worm activity, disease, and invasion by leather jackets. Then a house may have been empty for some time with the result that the sward may have developed into a tangled mass of unkempt grass.

Where a bad start has been made and the turf is water-logged it is best to lift and re-lay after giving attention to the surface soil. If, however, the soil is good while water-logging is bad, the drains may be faulty or inadequate and need attention; but where the condition is not very bad surface tubular forking may be sufficient to effect an adequate improvement. At any rate, in wet conditions tubular forking could be tried first before embarking on the major operation of re-laying or draining.

The presence of wrong grasses like perennial rye-grass may also be cause for re-sowing, but very often much improvement

can be brought about by renovating the surface with seeds of better grasses and later keeping the turf constantly mown, thus gradually destroying the coarser growths.

On a neglected lawn where the grass has grown long the first procedure should be to scythe it down and then to allow the sward to recover. It may then be possible to gauge whether there is sufficient bent or fescue grass present to make a permanent turf possible. Some little time may be allowed to elapse in order to obtain this information, and if bent and fescue are present in sufficient quantity the turf can most likely be brought into condition by general treatment with fertilizer or by weed-killing mixtures. If some cocksfoot is found it can be depended on to die out as a result of regular mowing and treatment. On the other hand, the mowing may reveal coarse grasses like rye-grass and Yorkshire fog, as well as weeds; in such an event a new start is probably the best. It is often cheaper in the long run to take the "plunge", skin off the old turf, cultivate, fallow and re-sow with fine seeds.

In lawns where weeds have become prevalent regular treatment with one of the mixtures advised may be given, and the nitrogen in the dressing will do much to encourage the grasses. Some renovation with seeds may also be wise. If the turf is reasonably free from weeds, though thin and sparse, it will probably respond to a general fertilizer, followed by a dressing of sulphate of ammonia and careful attention to mowing.

Neglected turf often becomes worm-ridden and here eradication of the pest is the primary necessity. Another sign of neglect is moss—often more a sign of poverty than bad drainage or high acidity. Light raking and dressings of sulphate of iron and mixed fertilizer should be tried first of all.

Renovation with seed has already been mentioned; when it is to be carried out it should be preceded by mowing; the surface should then be vigorously scarified with rakes until the seed bed is formed. The condition of the turf at this point will look hopeless, but it is surprising how rapidly it recovers. If the lawn is poverty-stricken treatment with a compound fertilizer should precede the sowing, which should then be followed by light composting and rolling. The seed should then be scattered on the surface and worked in by matting or brushing. In these circumstances it is difficult to obtain a really good seed bed in

comparison with one made by full cultivation, so that very often the establishment rate of the grass is poor.

Where space permits a turf nursery is a great stand-by. Patches containing Yorkshire fog or pernicious weeds may then be cut out of the lawns and new turf inserted. Hole cutters up to 10 in. in diameter may be had for this purpose. Needless to say the nursery should match as closely as possible the lawn on which it is to be used, and in laying small turves in this manner they should be placed level or slightly below the general surface. The level can always be made up by top-dressing later.

Fungal diseases of turf are often caused by wrong treatment rather than neglect, although failure to deal with an attack sometimes leads to almost complete loss of the turf. It is therefore best after diagnosing the presence of disease to apply a fungicide. The same remarks may be applied to leather jackets, which if neglected and present in sufficient number may cause very serious harm to the lawn.

In conclusion, it may be said that attempts are often made to resuscitate turf by various processes of renovation, when the quickest and cheapest way would be to start again. If mosses, rye-grass and resistant weeds are present in abundance this alternative should be favourably considered. A fresh start provides a golden opportunity for thorough cultivation, with perhaps catch cropping, as well as for soil amelioration using organic matter, with gritty materials in addition when the soil is heavy.

Chapter Thirty-one

Some "Don'ts" in Lawn Upkeep—A Summary

Most of the common mistakes made by lawn owners in establishing or managing their turf have already been mentioned in their appropriate context, but it may perhaps be of assistance if such failures be summarized in this chapter.

The secret of establishing a good lawn is to make a good start; the preparation should not be hurried or skimped because this will most certainly lead to increased maintenance costs in the future. When operations are being planned it is important to look ahead and to bear in mind that a turf sward is permanent and that the period of construction offers the only opportunity for materially altering the physical nature of the soil.

The work of sodding should not be left until after the end of January or early February. It is true that good results are sometimes attained by turfing later than this, but the risks of drought damage become greater the longer the work is deferred. On sandy soils earlier turfing is better. Further, it is well not to use sods of uneven thickness, not to beat the sods into position, and not to roll heavily. On a well-prepared sod-bed, using good turves, the latter operations are not necessary.

Except in warmer districts, sowing a lawn in the latter part of the season is best done no later than the end of August if good establishment is to be obtained. Sowing in spring should not be done before buried weed seeds have had an opportunity of germinating. Sowing should never be done on a bad seed bed or on one containing ungerminated weed seeds. Neglect of the seed bed is often a cause of future difficulties, and sowing

clean seed on dirty land or bad seed on well-prepared land are both wasteful. Sowing should be done uniformly on a dry surface, and the seed should not be raked in too deeply. Sowing on heavy wet land should not be attempted until some pre-treatment has been carried out with sand and organic material. Cheap seed mixtures should be avoided: they usually contain rye-grass and are often impure also. For the finest lawns rye-grass mixtures are quite unsuitable. Good quality blendings may, however, be used for second- or third-rate results. It should be remembered that grass seeds can be bought by name like the seed of any other plant; most merchants will state the purity and germination. These figures alone may be misleading unless something is known about the nature of the impurities. Seeds mixtures with many species have been found unnecessary, therefore for most purposes it is best to buy simple mixtures containing species or strains designed to meet the special requirements of fine turf.

Many lawn owners are mistaken in fertilizing their turf excessively so that a soft lush growth, susceptible to disease, results. There is sometimes a tendency to listen to agricultural advice and to scatter raw dung on the turf. This is usually harmful, and it is better to allow the manure to decompose first in a compost heap with soil. The last fertilizer dressing of the growing season should not be given later than the end of August or early September, though bone meal or compounds in which it is the main ingredient may be given later. It is perhaps unnecessary to point out that fertilizing in winter is both harmful and wasteful, yet at times this mistake is made. When manures are purchased some attention should be given to the value of the material as plant food, always realizing that small quantities of materials are proportionately more expensive to buy. Faulty distribution of the fertilizer on the lawn may be the cause of uneven colour or perhaps scorching of the grass. With a little patience and ingenuity uniform spreading may be achieved by stringing off the turf and by bulking with a carrier if a distributor is not available.

When top-dressing with sands or charcoal smothering of the grass must be avoided, or it is likely to be checked and disease may then appear. If there is danger of this it is better to make the application in two half dressings; such dressings are best given before growth finishes in the autumn or just after it

starts in spring. Sands containing clay particles should be avoided, as also sands of the moulding type, since both tend to bind in the turf and produce a compact layer. Sands containing lime should be avoided unless there is no alternative and unless there is some special reason for using them.

It must be remembered that mowing the lawn at long intervals is undesirable. It should be done regularly in accordance with the growth of the grass. Spasmodic cutting is harmful to the grass and deprives the soil more heavily of plant foods. Mowing two or three times a week is to be preferred, provided that the blade is not too low.

In the winter the grass should not be allowed to grow long or raggy, and occasional topping is desirable. There are points both for and against the return of the clippings. On the whole it is wise not to return them consistently, but only when they can be of service as a mulch in dry weather. The best results are got by regular switching before mowing and by mowing in different directions. Shaving the grass short in winter and early spring is harmful and the blade must be set higher than in the main growing season. With newly-sown turf, intensive mowing is harmful and topping is all that is required until the sward is well established, and in this connexion particularly a blunt or badly-set machine should not be used since it will "drag" the tender seedlings.

Most intensively-managed lawns must be watered but the top should not be sprinkled lightly in the belief that frequent light waterings are the best. An occasional thorough soaking is preferable, and it is easy to examine the turf to see how far the moisture has penetrated. Routine pricking is often omitted, but this is a mistake, because it is an aid to water penetration. Dry areas in summer benefit from local hand pricking. Slow application with a fine mist is best, and uniform application should be aimed at so that the turf benefits evenly throughout the sward. One way of aiding penetration is to apply a portion of the water, then to return after an interval and apply the rest. Watering should commence before the soil is showing serious signs of drought.

Worming is an operation in which failure to get results has often been due to the choice of wrong weather conditions. A cold atmosphere or dry soil are unsuitable; mild muggy conditions should always be chosen. If mowrah meal is used a

copious supply of water is necessary. Old stocks of meal often fail to give good results, but success may sometimes be achieved by using heavy rainfall, though it may happen that the rain ceases just after the meal has been applied to the turf, so that the meal is wasted. If it is not possible to worm, switching or brush harrowing as a means of scattering the casts should not be neglected. Lime water should not be used as a worm eradicant.

A frequent cause of neglect is weed invasion, and it is best to carry out eradication by a gradual process rather than a sudden one. Lawn sand and similar dressings referred to in the chapter on eradication should not be applied during drought, and must be carefully used on very matted turf since this is apt to suffer badly and to recover slowly. On the other hand, lawn-sand mixtures should not be used during wet weather or their scorching action on the weeds will be lost, and the material may simply "feed" the weeds. The optimum should be dry conditions with a moist soil. When eradicating weeds many lawn owners expect a magical recovery of the remaining grass. Very often it is essential to renovate the area with seed. The grass surviving from weed-killing work may, for instance, be only a shy creeper or even a tussock-former incapable of spreading over the bare ground. Occasional dressings of general fertilizer supplying phosphate and potash should be given, if weed-killing work is being carried out systematically.

Rolling is usually abused. An occasional rolling may be necessary, but the modern machine does a good deal of compressing. Worm casts should not be rolled out. This is harmful to the turf. Many lawn owners fail to appreciate that they can get better results by top-dressing to produce an even surface than by rolling. Rolling when the grass is thin or the surface very wet is harmful, and for most practical purposes on lawns a 2- or 3-cwt. roller occasionally used will meet the purpose.

Neglect of aeration is one of the commonest faults on lawns and turf used for games. Over-compression can be relieved by forking or spiking, which not only assists surface drainage and root formation but air entry and better use of fertilizers. Routine use of spiking machines on lawns is much to be commended.

The lawn mower is a vital implement in lawn upkeep, and must not be neglected; after use it should be cleaned and dried. Periodical greasing and setting of the blade is necessary, but

one must not expect the perfect finish produced by an expensive fine cutting machine from one costing a fraction of the money.

It is impossible to make rules for all classes of turf and all conditions, and therefore as a final word of caution the lawn owner is advised to obtain advice in abnormal cases. Many examples could be quoted in which a lawn owner "thinks" he knows, adopts a certain line of treatment, and having done so asks afterwards whether he has made the right decision!

Chapter Thirty-two

A Diary for the Year

No hard and fast time-table of operations in the upkeep of lawns can be made. It will be obvious that it is impossible in a general account because of the variations in local climate and season, individuality of the turf, the altitude and the nature of the soil. The diary given must therefore be taken as a general guide or indication as to the approximate time at which operations should be done, and variations will be necessary to meet individual cases.

January. This is often a bad month as regards weather, and in wet and snowy conditions outdoor work may be impossible, so that preparation of composts, ready for the season, should continue. Constructional work may probably be in hand and returfing should be finished off during the month, whilst during hard frosty weather the opportunity should be taken to complete carting work. Wet periods provide an excellent chance to study the correct working of the drainage system. Mowing is unlikely to be necessary, so the machines can be overhauled. A light dressing of bone meal at this time of the year and in the following month may be given and when turf is used for games like golf, care should be taken that it is not damaged by play immediately after a thaw.

February. The bad weather may continue, but in damp, mild periods a start may be made with de-worming, or if it cannot be done brush harrowing on large areas and switching on small areas may be carried out in dry conditions to scatter the casts. It is a good plan to compost lawns in this month, or if the turf is soft and springy $\frac{1}{8}$-in. mesh or $\frac{1}{6}$-in. mesh wood charcoal

may be applied after spike-rolling or deep spiking. Any land that is in course of preparation for spring sowing should be well cultivated this month, and mossy turf may be dressed with sulphate of iron in preparation for later treatment.

March. Often in March there are signs of growth that may be misleading, but on no account should the turf be keenly mown. If desired, topping may be done with the blade set high, since cold weather often intervenes and newly-mown grass is susceptible to wind damage. After frost has lifted the turf, rolling on a dry surface may be carried out once or twice. Light sanding and application of charcoal are useful, and towards the end of the month, the weather being open, the first dressing of artificials may be applied. In northern parts or higher altitudes it is better to defer this until the early days of April. Hand picking of weeds and de-worming may be interspersed. Land for autumn sowing should be dug before the end of this month.

April. The frequency of mowing is usually increased in accordance with weather conditions, which may or may not be conducive to growth. Renovation of existing turf with seed should be carried out, and if leather jackets are present, eradication with ortho-dichlorobenzene emulsion is advisable before damage becomes serious. The opportunity of doing this may occur earlier. Towards the end of the month a further light dressing of artificials or a dressing of sulphate of ammonia with compost may be given, and at this time of the year a light attack of Fusarium patch disease may appear. Switching before mowing, and preventive spraying with malachite green and Bordeaux mixture is advisable. With newly-laid turf, additional composting should be carried out.

May. Except in warm districts, where sowing may be done in April, the seeding of new turf should be carried out this month after ensuring that the dormant weed seeds have been given a chance to germinate. When the new seedlings are up they should not be over-mown. In May and June annual meadow-grass seeds profusely, and if it is desired to check it, drag brushing to raise the panicles should precede mowing. From now on mowing will occupy an increasing amount of time and it may be made more intensive. There will be a tendency for other

operations like hand picking of weeds and weed killing to be crowded, but they should be continued where possible in the intervals.

June. Mowing is in full swing this month, and as dry weather often intervenes care should be taken to raise the blade and allow the cuttings to return as a mulch. Light composting is beneficial and artificial watering preceded by spiking may be necessary. It is too late to use exterminator for leather jackets. Fallowing of land for autumn sowing should continue this month and the next.

July and August. Light fertilizer treatment with sulphate of ammonia is advisable and careful regulation of the mowing. There are signs of growth falling off in these months and of the encroachment of weeds like pearlwort. On the first sign of pearlwort it should be removed bodily or dressed out. The first batch of crane-flies may be emerging from the turf towards the end of August, and opportunities may occur for switching these as they emerge, so killing large numbers. If artificial watering is necessary, pricking should precede it. Final cultivation of land to be sown should be finished by the third week of August. Weed killing may be done, and the last fertilizer dressing of the season should be completed on established turf.

September. Seeding of new areas is best completed before the end of August but in milder climates it may continue into the early part of September. The new sward should be watched carefully for damping off, and if any signs appear spraying should be done. Preliminary worming work may commence unless the soil is too dry, at any rate the worm killer may be secured and the worming plant got ready. Top dressing with sand and charcoal towards the end of the month is advisable, and hand forking and spiking may commence. The amount of mowing should be reduced, the blade being raised.

October. Towards the end of September and in October, Fusarium disease may become serious, and if so spraying should continue at intervals. Worming, hand forking, and spiking are all seasonable, whilst constructional work should commence. Composting of the turf at this time of the year is desirable, and

of course much time will be taken up in sweeping up leaves where trees surround the lawn.

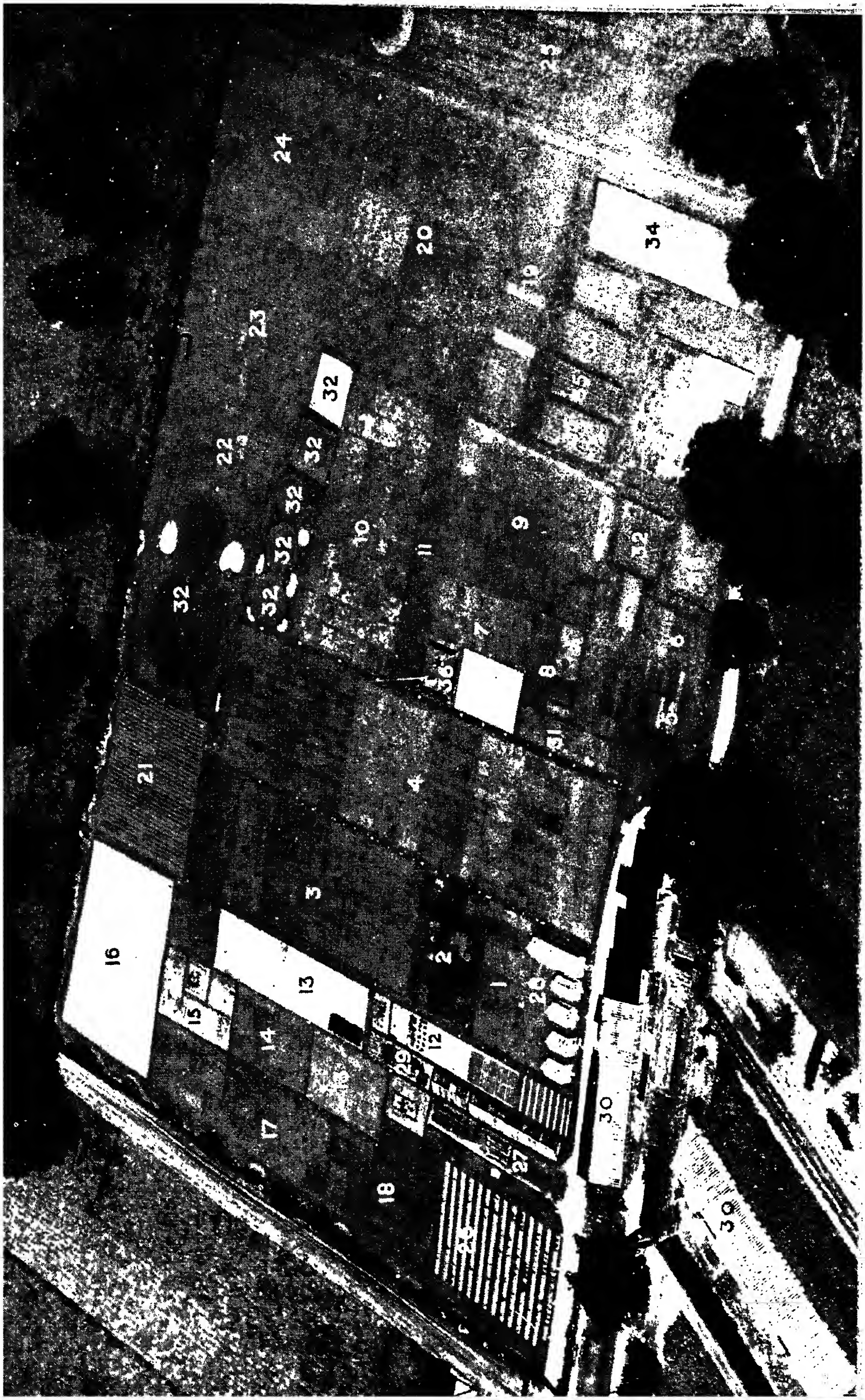
November and December. During these months testing for the presence of leather jackets, if suspected, should be carried out, using small quantities of ortho-dichlorobenzene exterminator for the purpose. A decision may then be made as to whether to apply lead arsenate. If the numbers are small they may be left and extracted in early spring with the exterminator. They are usually too small in early winter to enable them to be picked up. Constructional work will now be at its height, and on light soils re-turfing should be completed. The weather in these months may interrupt operations, and the preparation of compost can then be started. If applications of lime and slag are to be given, these months are suitable, whilst bone meal may also be applied.

SECTION IV

TURF FOR SPORT AND OTHER PURPOSES

Fig. 30.—An aerial view of the main Experiment ground (area 10 acres) at St. Ives Research Station.

1. Seeds mixture trials.
2. Comparison of heavy and light dressings of S/A and S/I.
3. Mechanical treatment of turf.
4. Manurial trials on different grass species.
5. Weed control experiments.
6. Trials of Agrostis strains from overseas.
7. Seeds mixture trial.
8. Top-dressing experiments.
9. Seeds mixtures.
10. Manurial trials on local turf.
11. Seeds mixtures for golf fairways and playing fields.
12. Comparison of different grass strains.
13. Reserve.
14. Top-dressing trials.
15. Propagation.
16. Now comprises trials comparing organic fertilisers.
17. Top-dressing trials.
18. Effect of height of cut on sward.
19. Comparison of varieties of Agrostis alone and in mixtures.
20. Worm-killing experiments.
21. Comparison of the effects of height and frequency of mowing.
22. Effect of sulphur on turf.
23. Worm-control experiments.
24. A comparison of 6 manurial and other factors in all possible combinations in their effect on turf.
25. Reserve land.
26. Grass and weed museum.
27. Pot experiments.
28. Plant breeding.
29. Grass selections.
30. Glasshouses.
31. Cumberland turf.
32. Putting green.
33. Bowling green.
34. Reserved for tennis-court turf.
35. Tees: sown with different hard-wearing mixtures.
36. Weather Station.



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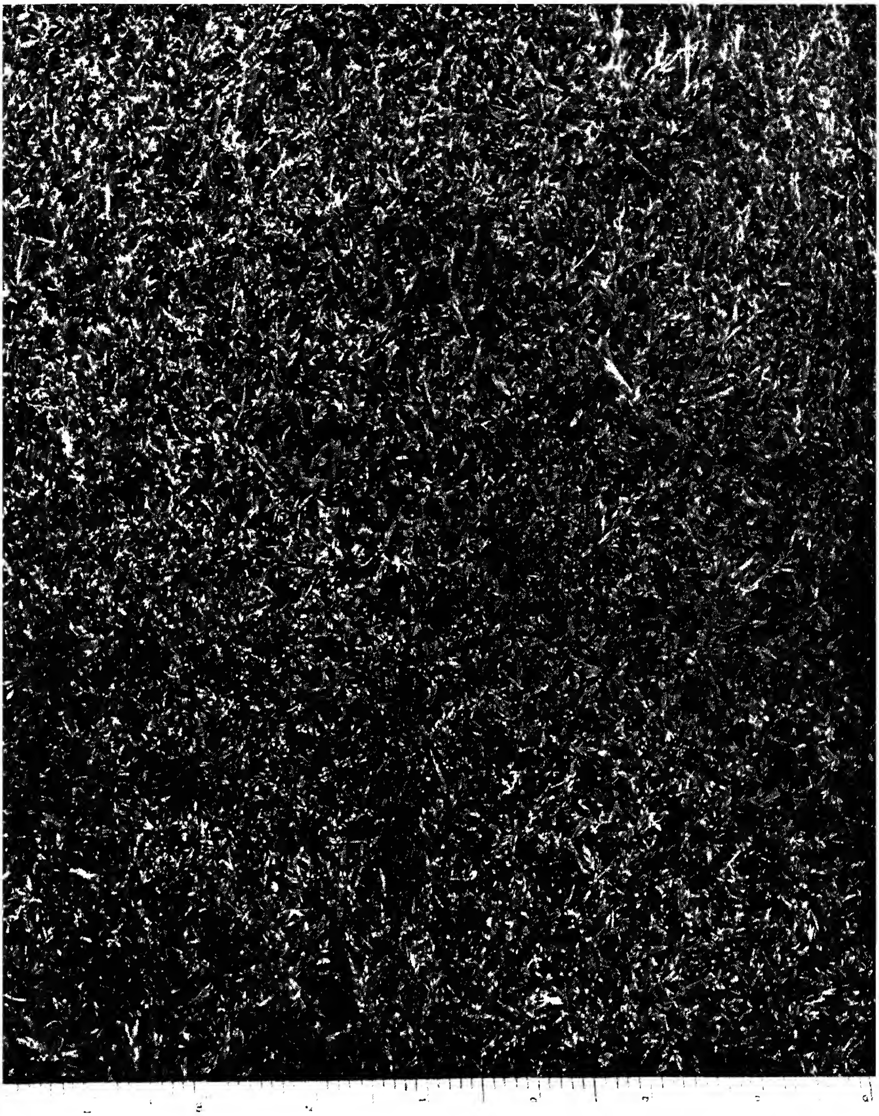


Fig. 31.—Established turf: Annual meadow-grass.

Chapter Thirty-three

Golf Course Management

he management of turf to meet the requirements of the game of golf is a subject worthy of much wider treatment than is possible in one chapter of a book dealing with general lawn upkeep. It is impossible, therefore, to do more than bring together the salient features and the broad lines of treatment that should be adopted in practice. Not the least difficulty in treating the subject is the large area of land involved. On the same course the soil may in one part be light-sandy and on another extremely heavy; there are almost certain to be variations in aspect and altitude. Further, for the purpose of the game the separate portions of the course, namely, greens, fairways, and tees, demand different grades of treatment. Then there are the natural differences between courses, as well as differences created in their evolution through passage of time or in construction. Some courses are built on ambitious lines whilst others are simpler or have been evolved from small beginnings. All these factors together make the subject a wide one, and it may well be imagined, therefore, that no set course or programme of upkeep can possibly be laid down, much less can the attempt be made in one chapter to deal adequately with all aspects. All one can hope to do is to indicate the many problems of management and the basic principles involved. Many of these have already received detailed description in considering the upkeep of fine lawns, and the chapters dealing with seeds, fertilizers, diseases and pests should be freely consulted.

Upkeep of putting greens on golf courses is the most intensive form of turf culture, and this alone introduces special problems. As distinct from other games golf is played all the year round,

the others being either summer or winter sports, although on many congested grounds the same ground is used. This alone introduces special difficulties, for example, continuous wear and tear, often of an insidious nature, the difficulties of maintaining a good putting turf in the winter, and the difficulties of finding a period when drastic renovation or re-construction can be done without undue interference with players. All work on golf greens must be done by stealth, and the expert greenkeeper is a past master in treating his turf with the minimum inconvenience to the players, who, if they are of first-class calibre, will object to even trifling inconvenience. Surmounting of these difficulties has evolved a type of greenkeeper who is resourceful and capable of dealing with almost any eventuality; who is a keen observer, artful yet artistic, and though seldom appreciated to the full by those he serves, is worthy of our respect.

In establishing a new course it is first necessary to consider the proposed site as to whether it provides suitable natural features on which to lay out the holes. The services of a golf architect are best enlisted since he will be able to judge of the potentialities of the land and to make the most of them in laying out the holes with gentle undulations which will bring out a variety of shots, so providing interesting playing conditions. Ample space to avoid cramping is essential, and the artistry of landscape construction must always be considered. Natural attractions like gently undulating land ornamented with heather, gorse, broom or other plants make the best golfing country. The best turf for golf is undoubtedly found on heathlands, old parklands and seaside links where the finer-leaved types of grass like the bents and fescues are dominant. On moorland courses moor mat-grass and wavy hair-grass also occur whilst on seaside links red fescue is often a dominant grass. On many seaside courses there is a tendency for moorland conditions to develop with an increase of bent and grass species found on peaty soils. Unfortunately many courses are laid on land which gives no help to the architect, so necessitating a good deal of landscape work.

Course design is more art than science, and is a subject upon which there are many conflicting opinions. It is beyond the scope of this account to deal with golf architecture, but some of the points upon which there is general agreement are worthy of inclusion here.

The present-day fashion in architecture is "strategy", and the setting of a series of conundrums so that a player has to think out the best shot to reach the hole. The game should provide both mental as well as physical exercise. Fairway bunkers should be designed to govern the play of the hole and should penalize the scratch player's shot that has not been quite good enough. There must always be alternative routes to the green for short and long handicap players. The lay-out should encourage the player to incur a risk in the hope of securing a definite advantage, and the reward, if he is successful, should be proportionate to this risk. As to greens, these should be orientated properly and guarded with bunkers to catch the shot not played skilfully enough.

Every advantage should be taken of the natural features of the land, and the lay-out should be such that if possible no two consecutive holes are played with or against the same wind, and each hole should have distinct characteristics.

In constructing a course the artistic sense must have full play, and in making artificial features like mounds, hillocks, and hollows, they should be fashioned as though the natural process of wind and rain erosion had been at work. Good natural scenery with undulations enables the architect to present new views at each hole.

The general course length should not be below 6,000 yd. nor longer than about 6,500 yd., but there is to-day a tendency to extend still further. Preferably there should be three loops of six holes radiating from the clubhouse, or if the land does not permit this then two loops, so giving two starting points. The "up and down" or grid-iron system of lay-out is dull and should be avoided, but of course the lay-out is very dependent upon the shape of the selected land and the funds available. Unfortunately land is often secured for golf-course purposes without first of all exploring its ultimate possibilities for a well-designed course.

The cost of constructing a course is very variable and no exact figure can be given. Some courses in which much landscape work and sowing was involved have cost as much as £14,000 to £16,000, but less ambitious courses costing from £3,000 to £6,000, according to the nature of the land and requirements, are more usual. Many well-conceived schemes have been spoilt at the outset by faulty construction, by pro-

viding inadequate top-soil and by spending too little on cultivation and pre-treatment before sowing. Very often inadequate drainage and bad bunker construction lead to increased upkeep costs as well as much inconvenience to players for many years. In laying out and constructing a course it should be borne in mind that the course has subsequently to be maintained, therefore big undulations on a green surface, for example, should be avoided, and an adequacy of top-soil always provided. Whilst large undulations are no doubt spectacular they lead to many upkeep problems, such as skinning of the turf by the mowing machines, shortage of space for the pin, and the mowing of large areas that are unnecessary and do not "earn their keep". On heavy land new greens should be adequately drained, whilst on lighter soils provision of water for coping with drought is now considered an essential. The chapters on drainage and watering should be consulted.

The method of sowing and pre-treating land should follow the lines laid down earlier in this book and thorough cultivation of the soil is essential. For putting greens there can be little doubt in the mind of anyone who has carefully studied the subject that a stand of bent, or of bent and fescue combined, gives the best all-round results. In practice, however, most greens contain a mingling of annual meadow-grass among the bent and fescue shoots, and one of the problems of golf-green upkeep is to keep this annual meadow-grass in subjection whilst favouring the bents and fescues. Many beautiful fescue and bent turf greens, particularly on seaside courses, have been lost through the adoption of treatments more favourable to annual meadow-grass than the fescue and bent. The fescue and bent greens are more closely associated with the lighter and poorer soils, but on heavy land greens consisting of almost a pure stand of annual meadow-grass are more frequently found.

To be a good golf green it is necessary that the surface should be true—and the golfer will excuse many blemishes provided he is able to putt accurately. Uniformity in colour and speed of the turf are important, and the grass should be capable of holding the ball on the line of the putt. The surface must be sufficiently well managed to resist wear and tear for twelve months of the year, and it should be reasonably resistant to dry weather. A good green should never be absolutely flat; undulations must be provided and sufficient space must be left for placing changes

of the pin. Long, gentle undulations are best in which, with a flat space of at least one yard around, the position where the hole will be placed. The greens may be tilted to the left or the right, so necessitating greater skill in judging strength of stroke and direction. The surface of the green must be visible from the point at which the stroke to the green is played.

The difficulties of playing for twelve months of the year have already been mentioned, and in view of this great care is necessary with the greens in the winter months, especially during frost, when damage is likely to be severe. Clubs that are fortunate in having good approaches to the greens often close, or temporarily close, the putting surface for a resting period, and this is beneficial—though rarely received with equanimity by the golfer.

During the growing season mowing occupies the bulk of the time of the ground staff. Here uniformity through the 18 greens is necessary, and roller machines with 8 or 10 blades are now usual. Many greens, however, are cut much too closely, and better results would be obtained by raising the blade slightly and cutting just as frequently. Boxing of cuttings, rolling and aerating have already been discussed in detail under the upkeep of fine lawns, and reference should be made to the appropriate chapters.

Top-dressing is a subject to which some special reference may usefully be made. It has already been stated that a true surface is essential, and to-day this condition is produced by top-dressing with composts, sand, and charcoal for the purpose of filling the depressions, rather than by heavy rolling to compress the lumps. The preparation of compost heaps, a sterilizer, and suitable apparatus for preparing the dressings have already received notice in earlier chapters. Composting has largely become a standard operation. Weed problems on golf greens as well as fairways are often serious, and reference should be made to the appropriate chapter. Perhaps the most persistent and difficult weed on putting greens is pearlwort, after which may be placed mouse-ear chickweed, clover and yarrow.

The approaches to golf greens are often neglected. Their purpose is to merge the fairways into the greens and to provide a run up to the putting green. They should be maintained in condition somewhere in between the putting green and the fairways. Mowing should be done more frequently and more

keenly than fairways, and fertilizing, worm killing, and weed killing must of course be more intensive. A good approach is a stand-by when the green requires renovation or resting, and for this purpose alone the production of good approaches is well worth while.

Perhaps no portion of the golf course receives less treatment than the tees, yet these areas are the very ones that receive the severest wear and tear. Neglect of the tees is usual, and although it may be argued that provided the surface is level and not sticky, bare ground would be satisfactory, yet nothing is more objectionable than a tee that has been cut to pieces by clubs or worn by constant traffic. Most tees conform to the conventional rectangular shape, thus nullifying much of the artistry and natural setting built into the course elsewhere. Tees nearly always require some re-turfing where the course is intensively used, and at short holes often require annual re-sodding. The life of the sward may be much prolonged by ensuring adequate drainage, by removing earthworms, and by occasional applications of fertilizer and top-dressing. The request is often made for a special species of grass capable of withstanding wear and tear on a short-hole tee. It is doubtful whether any species of grass is tough enough to withstand the severe punishment meted out, and the problem is essentially one of paying greater attention to upkeep by re-seeding, by resting, and by having an area sufficiently adequate to enable play to be distributed, so giving the surface a fair chance for recuperation.

Most clubs neglect their fairways, though in recent years there has been a greater realization of the fact that constant wear and tear and regular mowing result in depreciation. Within reason the closer the "lie" on fairways, the better will be the golf. Much improvement can be effected on fairways by spiking or harrowing and applying a general fertilizer. Above all, de-worming effects outstanding improvement and many excellent fairways have been created out of a muddy sticky surface by the removal of this pest. The general lines of treatment accorded to fairways depend entirely upon the nature of the grass, the soil, and whether weed killing is involved. The programme adopted must therefore take into account the special conditions found, and to spread the cost a rotational system may be followed. Many instances are known, however, where fairways have been wrongly treated, with the result that

worm and weed infestation has become greater rather than less. In treating large areas, where considerable sums of money may be involved, it is always best to obtain the advice of those who have made a special study of the problem.

The remaining turf areas on a golf course constitute the "rough", and in recent years on many courses the tendency has been almost to eliminate this. This is understandable because an overgrown tussocky rough leads to much inconvenience and delay through search for lost balls. Many clubs have been compelled to add to their cutting machinery in order to cope with this additional burden. Unfortunately, to mow in this manner leads to a certain monotony of play, but by judicious planting of gorse, broom and heather, great improvements can be effected to the artistic appearance of the course. Certain grasses are also useful, namely, sea-lyme grass and marram on seaside links, and *Brachypodium* and tufted hair-grass on inland situations. These plants help to break up the ground, and with flowering shrubs much beauty may be added. Merging of the rough into the fairways and other parts in play should always be the aim.

Grazing of sheep on courses is often a vexed question. No doubt sheep help to reduce weed invasion, but the objectionable fouling of the land and the damage to bunkers usually results in more being spent in upkeep than brought in by rental. No first-class course now supports sheep if they can be dispensed with, but unfortunately some clubs only occupy the land on condition that grazing be carried out, whilst in other instances common rights prevent the exclusion of ponies and other stock.

Every course should have its turf nursery ready for reconstructional work or patching damaged greens. It may be worked down from the natural turf or prepared from seed upon a cultivated area.

It is interesting to reflect that the best courses found to-day are laid on sand dunes, moors, heathland, and commons, that is mainly upon the poorer types of soils which are less suitable for agricultural purposes and support the finer types of grass. Unfortunately, through lack of alternative sites, many courses have been laid on land that could be more usefully employed for crop production, and it is felt that in the future more consideration should be devoted to the utilization of waste land

which could not be brought into crop bearing condition without a tremendous expense. These poor lands support the right types of grasses for turf, require the minimum of fertilizer treatment and, above all, need minimum attention from the mower. There must be many areas of poor land of this type that would make excellent courses, and to which access can now more readily be attained since the introduction of easier and cheaper transport.

An eloquent appeal has been made by Sir R. G. Stapledon [65] in his book entitled *The Land, Now and To-morrow*, for the provision of more golf courses. It may be held that the number available at the present time is ample to meet the demand, but the author argues that golf is the best way of enjoying beautiful scenery and obtaining healthful exercise while still participating in a game without being unpleasantly crowded. He states that playing a game makes at least some demand on persons' originality and personality, and he pleads for a greater number of what he calls "primitive" courses, that is courses that have cost a fraction of the usual amount to construct, where there will be no luxurious clubhouse, where the fairways will be broad rather than of good texture, and where the greens will be small and the hazards few and of a natural type. Stapledon claims that if primitive golf at low expense could be adopted by the masses of people it would form the best antidote to the hurry of modern life, the best cure for the mass psychology of modern town-life, and a step towards the right use of leisure. For such primitive courses to come into existence would necessitate golf developing into a rage as did the cinema and dog-racing some years ago and he firmly believes that there is a need for greatly extended facilities for primitive golf.

One of the first necessities in maintaining a golf course, however, must be a first-class greenkeeper conversant with up-to-date ideas, willing to co-operate with the club secretary and chairman of the green committee in general maintenance work and in making minor constructional improvements to the course. Larger improvements are the prerogative of the golf-course architect who has studied his subject and has a flair for lay-out. In practice one often finds that as soon as the mowing season is over the ground staff on a golf course are ordered to construct a new green, to fill in a bunker or make a new one,

[65] Stapledon, R. G.; Faber & Faber, London, 1935.

to remove a mound, or to carry out some such non-essential piece of work. This is the bugbear of greenkeeping, since a well qualified man will always have plenty of winter work in hand in preparation for the coming growing season. Another difficulty in maintaining courses is the tendency to experiment, and many good courses have been seriously damaged by ignorant application of some far-fetched idea. The present system of managing golf courses involves the election annually of a green committee. Whilst this may at times have advantages, it is usually detrimental to the course, since there is nearly always lack of continuity of policy through the changing personnel, and the members are generally business men who forget that grass is a growing plant and that it is subject to the vagaries of season and climate.

Chapter Thirty-four

Upkeep of Turf for Bowls, Lawn Tennis and Croquet

Most of what has been written in the earlier chapters may be applied to the upkeep of fine turf for the games of bowls, lawn tennis, and croquet, though some variation and allowances must be made in accordance with the requirements of the particular game concerned and the standard of excellence desired. Whilst management is just as intensive as on putting greens, there is the difference that absence of winter play provides a resting period when repairs can be effected.

Bowling Greens. The subject of bowling-green upkeep is one that can only receive broad treatment in these pages, but the ever-increasing popularity of the game and the establishment of many new greens (principally welfare and municipal) has brought so many more people into touch with bowling-green upkeep that a general account of management and some of the difficulties may be found helpful. The bowler is perhaps the keenest and most critical user of fine turf, and as many problems in the later life of a green are related to a bad beginning it is advisable to start by a consideration of the building of a new green.

Construction. Occasionally greens are made from seed, but the majority are sodded. There is no reason why a satisfactory green should not be produced by seeding, and, indeed, with the increasing difficulty of obtaining suitable supplies of turf, a confident forecast may be made that sowing will increase in the future.

The preparation of a green for sowing requires a longer period than for sodding, which is one of the disadvantages of this method. Moreover, a turfed green can be constructed during the winter months and be ready for play by about June, but a spring-sown green would be of little use for play until perhaps the late summer. If autumn sowing can be carried out, the green having been constructed in the summer months, play should normally be possible for the second half of the season, though the green would require careful managing. As constructional work on new greens is a winter job sodding can follow right away, whereas with sowing spring conditions must be awaited. It is vitally important only to use suitable seed and to prepare the site in such a way that it will ensure a permanent sward. Where sowing is carried out successful results have been obtained by using New Zealand browntop alone or a proportion of this species with Chewing's fescue. One method is to sow throughout with New Zealand browntop except for a strip around the edges on which Chewing's fescue is used in addition for extra durability. In brief, sowing solves the difficulty of finding good turf and the establishment cost is less though the start of play is longer delayed.

The usual type of turf employed for sodding flat greens is obtained from sea marshes in Cumberland (Solway Estuary near Silloth), Forres (North of Scotland), Lancashire (near Pilling and on the other shores of Morecambe Bay), and parts of South Wales. The prices and method of using this type of turf have already been mentioned. Sea marsh turf of this class contains mainly two grass species, *Festuca rubra* var. *glaucescens* and Creeping Bent, *Agrostis stolonifera* var. *compacta.* The relative proportion of these two species is very variable, not only between districts but from one area to another on the same marsh. Probably because of its uniformity and the presence of the fine fescue, the Cumberland turf has earned a high reputation in the past. With the increased demand for sea marsh turf other areas have been used, and very often the quality has deteriorated as supplies have been worked out. Some of this class of turf now contains a high proportion of creeping bent. On occasion the dominant grass is *Glyceria maritima*—a species unsuited to fine turf formation.

The "soil" in which sea marsh turf grows is in reality a fine silty clay deposited by high tides over the surface. When this

layer is compressed by rolling and treading on a green it becomes compact and so leads to difficulties in upkeep. It is true to say, though rarely appreciated by those who stress the value of the grass species present, that it is the ability of sea marsh turf to roll out into a keen flat firm surface that has largely earned the turf its reputation among bowlers.

Moorland and parkland turf closely boxed to remove excessive mat, and carefully top-dressed, merits increased attention in bowling-green construction.

In choosing the site for a green it is necessary to avoid heavily-wooded areas, and to select land with gradual contours, as it is best to dig out the formation level of the green on the solid. The flatter the site the lower will be the cost. If on the slope, the "fill and draw" method must be adopted and an adequate period left for settlement. Where a green is constructed near trees, the shade factor will cause difficulty in upkeep and there may also be trouble from the decay of roots in subsequent years. It is sometimes forgotten that a green must above all be convenient of access, and it should be adjacent to an available water supply.

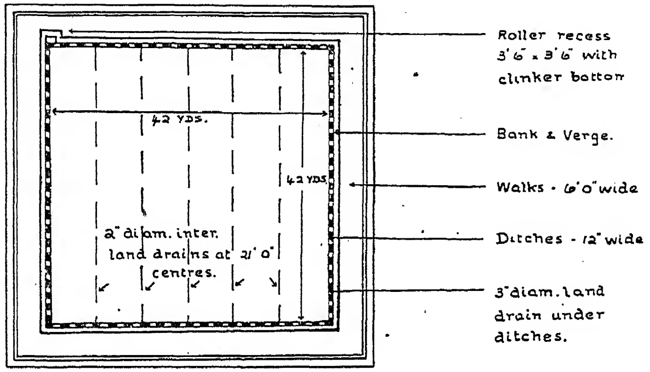
A flat green should be 42 yd. square maximum or 35 yd. minimum, but it is best to construct a full-size green of 42 yd. so as to allow for turning of the rinks to reduce wear and tear at the ends. The rinks should have a maximum width of 21 ft. and a minimum of 19 ft. For crown greens the usual size is from 40 to 45 yd. square with an 8- to 10-inch crown. Regulation size is 45 yd. square.

The site for the green must be stripped, levelled and embanked, after which a simple system of drainage is usually introduced. This may be on the herring-bone system with a 4-inch diagonal and 3-inch laterals whilst a 4-inch ditch drain pipe is laid 6 in. below formation level. The other method is the rectangular system in which there is a 3-in. or 4-in. pipe below the ditch with laterals sloping from the centre and collecting on either side. These are placed at 15 to 20 ft. centres using 2- or 3-in. bore pipes. The fall of these laterals should not exceed 1 in 40 and they should be cut into the formation level so that the tops are flush with the formation level at the highest point. They must join into the ditch drain. A drain is carried through the bank to a main drain or soak-away. Instances are known where the foundation level has been sloped and no

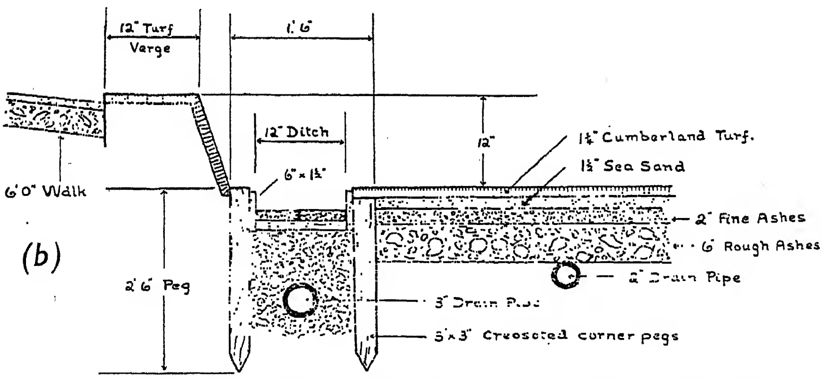
drains utilized except in the ditch. The indications point to many greens being excessively drained.

After the drains have been inserted it is usual to apply about three 40-gal. barrels of creosote to destroy worms and weed growths in the soil. Then a layer of broken stones may be put in and over them a layer of 5 to 7 in. of clinkers is usual. The

(a)



(b)



Text Fig. B.—Standard details of bowling green to E.B.A. requirements as generally adopted. (*a*) Plan. (*b*) Section through bank and ditch.

ditches should be 12 in. wide, supported by ditch boards made of 6-in. by 1-in. boards 10 ft. long securely nailed to cross pieces and pegs ; after partial filling with clinker, a top layer of gravel to a depth of 1½ to 3 in. is given. At times a board is used instead of the gravel. The top of this or the gravel should be 3 in. below the level of the turf surface.

In order to avoid sinkage in later years the clinker over the

surface of the foundation must be well consolidated by ramming, and then topped with at least an inch layer of fine ashes ($\frac{1}{4}$-in. grade and under). All hollows must be carefully made up. On top of the fine ash a layer of 1 to 2 in. of sand is placed, and upon this the 1-ft.-square turves are laid. It is usual to omit soil when laying a standard green with seaside turf, but on what exact evidence this has been decided is difficult to ascertain, because no critical comparative trials of the two methods of laying, using parts of the same green, have ever been carried out. Perhaps the ideal would be a minimum of 2 in. consisting of a mixture of equal parts of soil and sand so as to encourage root development and resist drought yet not unduly impair surface drainage.

On flat greens turfing is done in the diagonal direction but crown greens laying should begin at the centre and proceed radially in concentric rings. The laying must be carried out carefully so as to ensure uniformity of surface. After the turves are laid they should be rolled and given a dressing of sharp clean sand.

Banks are usually made 12 in. high with a batter of 9 in., though the English Bowling Association specify an 18-in. bank. There should be a 12-in. verge at the top of the bank arranged $1\frac{3}{4}$ in. above the surrounding path. Each green should be provided with a hydrant and a roller recess about 3 ft. 6 in. by 2 ft. 6 in.

When a green is to be sown the preparations are the same except that over the fine ash layer at least a 6-in. stratum of loam soil is added. If 9 in. can be given so much the better. The majority of crown greens made from inland turf are laid upon soil overlying ash, and these greens cause much less difficulty in upkeep than sea marsh turf on pure sand or sandy soil.

Upkeep. As the construction of flat greens is more or less standard it might be expected that all greens could be maintained on a common plan, but experience shows that greens differ markedly and that the variations in the programme of treatment are considerable. The skeleton treatment usually applied to a bowling green involves autumn and spring fertilizer treatment, forking and sanding, whilst hand picking of weeds and careful management of play are necessary to get the best results. A common autumn treatment involves tubular

forking followed by a dressing of bone meal and 6 to 8 tons of sharp clean sand and in the spring a dressing of general fertilizer. One or two inter-seasonal dressings of sulphate of ammonia, preferably in solution, are usually required also.

Tubular forking is particularly valuable on turf of the sea marsh type because the layer of silt in this turf becomes very compact and fails to encourage root development. It also bakes hard in summer. Perforation by tubular forking leads to a marked improvement in growth and in root development. Sea marsh turf readily "caps" on the surface so that spike rolling, mechanical raking and harrowing are necessary. The operation of forking a flat bowling green should start in one corner and proceed diagonally.

It may safely be said that all sea marsh turf suffers sooner or later from invasion by annual meadow-grass, and often it would be true to say that the sea marsh turf has merely acted as a temporary sward until this volunteer grass becomes well established. Evidence points to *Poa annua* being favoured by the heavy use of mixed fertilizers though in some instances the tendency is for creeping bent to increase first of all at the expense of the fescue, since it can spread rapidly with its vigorous runners. Meadow-grass invasion may largely be checked by maintaining the green with a minimum of fertilizer and by regular brushing at flowering time, combined with boxing off the clippings.

The problem of preventing invasion of annual meadow-grass, or of eradicating it once it has entered a green, is one of great difficulty, but experiments have indicated that it may be possible to spray greens with a dilute solution of poison of such a strength as to kill the *Poa annua* selectively whilst leaving the fine grasses, bent and fescue, only temporarily harmed. Such treatment would, of course, involve a period in which the green was thin and of poor colour, and it cannot be attempted without expert advice and a botanical analysis to ascertain whether there is an adequacy of bent and fescue eventually to take the place of the *Poa* destroyed.

Common weeds encountered in sea marsh turf are sea-milkwort, sea-plantain, starweed, sea-pink or thrift, and scurvy grass. Perhaps the sea-pink is the commonest of these species, and regular hand picking for several seasons is usually necessary to eradicate this plant. Some poorer grades of sea marsh turf

contain clover, which is in little evidence until regular mowing begins or when dressings of phosphate may favour its rapid spread. Scything of clover is commonly carried out and raking to pull up the runners. Weeds that invade the turf and may prove very serious are pearlwort and chickweed.

It should be appreciated that a bowling green must provide a dead true, keen surface, capable of withstanding intensive play. The run of the woods must not be deadened by heavy growth and the green must be of such a nature that it drains rapidly after heavy rain. Freedom from weeds, disease, and other blemishes is essential, and a tidy well-managed green should be ideal. Some heavy rolling in the spring may be necessary (4 to $4\frac{1}{2}$ cwt. roller) to establish the surface, but there is a tendency on bowling greens to overdo this operation. Usually throughout the season the compressing action of a good 10-bladed roller mower is sufficient.

Other operations necessary in the maintenance of a good green are regular spike rolling, drag brushing before mowing, and seasonal rolling, for which an elm roller of about 100 lb. is usual. A hole cutter for patching and a mat for working in top-dressing are both necessary, whilst many clubs possess small mechanical distributors for applying dressings. In dry summers watering is usually necessary and should commence before the turf is dried out. Very few bowling clubs take the trouble to provide themselves with a small turf nursery made from sods like those used on the green. This is very important because often at the end of the season patches have to be put in, especially at the ends of the rinks or in the corners of crown greens. Further, few clubs maintain a small compost heap, but whilst heavy composting is not necessary, a small quantity is useful in distributing dressings or adding to sand or peat to make a composite material. If no room exists for such a heap then "made-up" top-dressings have to be used.

The management of the play on a green must be carefully studied by the man in charge, who must arrange that the rinks be turned periodically and that the wear is distributed evenly by occasionally missing out one rink so as to bring the wear at the rink ends on to a new position. Excessive wear on the edges of greens favours invasion of annual meadow-grass and loss of the finer grasses. The general methods of pest and weed control, and the principles underlying intensive management,

Fig. 32.—Established turf: Perennial rye-grass.

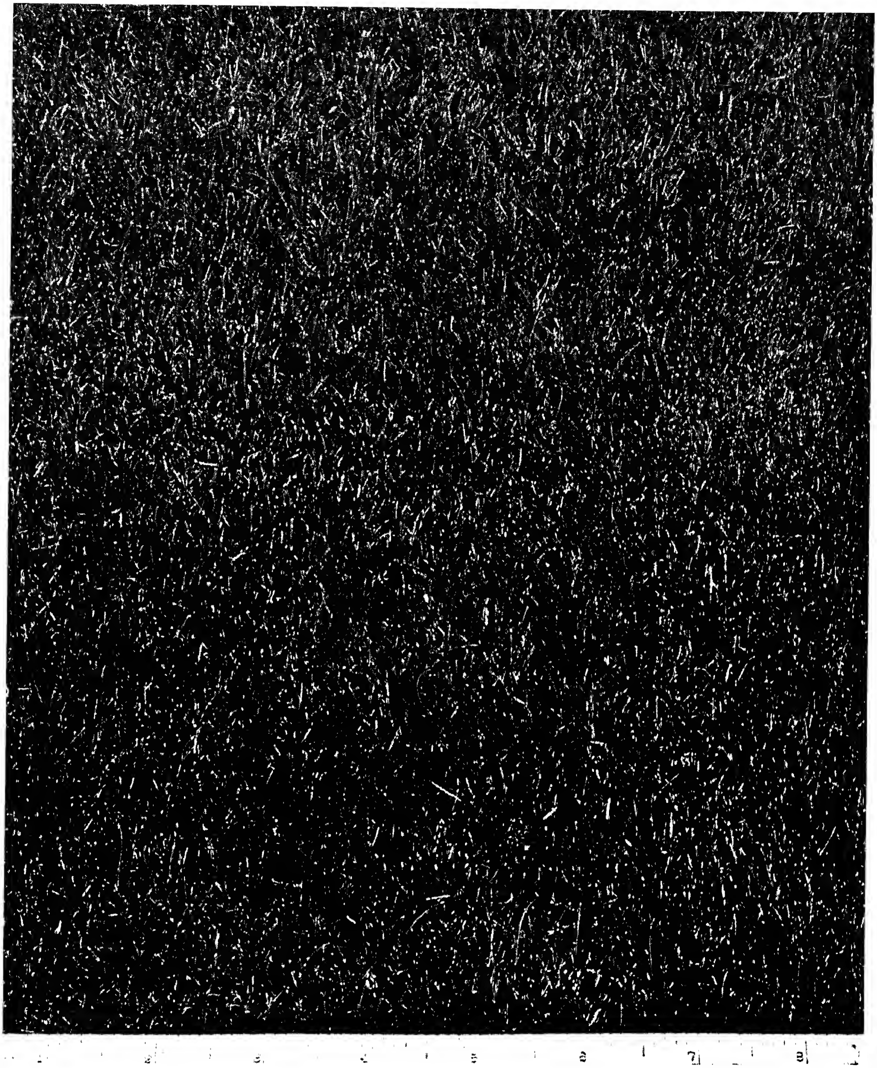


Fig. 33.—Established turf: Fine-leaved fescue.

are as described in the chapters in Section III, which should be consulted.

Lawn Tennis Courts. The general lines of upkeep on tennis courts should follow those laid down for the maintenance of a good lawn. It is essential, however, that trueness, firmness and uniformity should be secured in order to give a good and accurate bounce to the ball. The turf must also be sufficiently durable to withstand reasonable wear and tear, and to this end it is important that the herbage should not be so succulent as that required on, for example, a golf green.

In laying out a new tennis court the best orientation will be found to be NNW to SSE., though north and south will do. Good light is just as important as a good surface, and a suitable background of shrubs or trees is desirable. In laying out the site, adequate room must be provided, with plenty of run back and side run. A run back of 20 to 21 ft. and 12 to 14 ft. at each side of the court is the ideal. Careful levelling of the site is most important, and if excavation is done, an adequate period for settling should be allowed, though this will be less if the soil has been built up layer by layer and each one carefully consolidated.

A system of drainage is necessary on all but the lightest soils, and if the level area has been cut from a bank, a drain should be inserted at the foot. On heavy soils a layer of ashes 4 in. deep should cover the foundation level and then at least 6 in. and preferably 9 in. of good soil should be superimposed. A fibrous medium loam is the best, but as pointed out in the general section on construction of lawns amelioration with organic matter or gritty materials is important. Whatever is done, very careful levelling is essential.

In constructing courts there is the usual problem as to whether to seed or sod, and decision is usually determined by whether or not supplies of good turf can be obtained at reasonable cost. More and more lawn tennis courts are being put down to seed and the chapters about sowing seed and the purchase of suitable mixtures should be consulted. When the court is established, it must receive regular and careful mowing, and in management the aim should be to produce a hard true surface—rather like a cricket wicket. In attaining this ideal the soil may often become over-consolidated, but this condition

can be relieved nowadays at the end of the playing season by systematic use of spiking machines or once in, say, three years by tubular forking.

Earthworms often upset the surface of lawn tennis courts seriously, and their eradication is therefore imperative. Weed killing should also be carried out, especially if there is any tendency for plantains to spread on the hard surface in which it is able to thrive. Clover should be dealt with rigorously by raking and scything and by applying dressings high in nitrogen.

Most club courts and many private tennis courts suffer severe wear and tear, chiefly on the base lines, by the end of the season. As play usually continues until nearly the end of September, it is then too late to obtain a satisfactory establishment of seed able to withstand winter and the shocks of spring play. It has therefore become customary to repair the base lines by returfing. In doing this, many clubs import turf from a field or another site, but find that it fails to match and does not give good conditions for the following season. A better plan, therefore, is to utilize turf from the surrounds or from between the courts, the scars being then returfed with new sods or sown the following spring. The part that receives the maximum wear is a strip along the base line for a distance of about 11 ft. either side of the centre line of the court. Outside this, wear and tear is rarely serious. Sometimes where there is sufficient room, it is possible to make a left or right shift of the courts by some 20 or 22 ft., thus enabling the returfed area to have a season of reduced wear and tear, whilst the maximum play takes place on an area that has been longer established. After a second season, return to the original positions can take place. Sometimes where courts are placed end to end, an end shift is possible, placing the base line in the second year about the position of the service line of the first year. Naturally the practicability of such a device depends entirely upon the space available, and unfortunately many single or groups of courts are so hemmed in that there is no room to adopt this suggestion. As already stated, the general lines of manuring, spiking, and top-dressing should closely follow those laid down for general lawns, though care must be taken not to use heavy quantities of sand, which are apt to give a crumbly surface unable to last the season.

It is not within the scope of this account to deal with hard

courts, except to say that difficulty may be experienced in controlling moss. For this a common treatment is an application of a 5 per cent solution of caustic soda, but no doubt there are many other weed-killing materials that would achieve this purpose.

Croquet Lawns. For croquet lawns a fine, keen, fast turf, but not necessarily hard, is required, and the surface should approximate in quality to the finest type of golf green. The general lines of treatment to adopt are similar to those for golf greens, always bearing in mind the advantage that croquet lawns have in not being required during the winter months, at which time systematic forking, harrowing, and general renovation can be carried out without the disadvantage of interrupting play. The absence of undulations eliminates many of the difficulties of mowing, dressing, and watering so often experienced on undulating golf greens.

Chapter Thirty-five

Management of Football, Hockey, and Cricket Grounds

Hockey Pitches. In order to keep the ball on the ground and permit good stick work a keen, firm, true surface must be available for this game, and it is therefore necessary that the pitch should be well drained and reasonably level. Ridge and furrow land must be relaid and regular mowing is important to provide ideal conditions. Many old-established grounds are laid on matted bent-fescue turf, which, when well mown, rolled and spiked, gives an excellent dry surface during the winter months.

Rolling being necessary it is usual to find that the surface of hockey pitches has a tendency to retain moisture and for pan to form at a depth of 2 or 3 in. so preventing seepage and giving a wet spongy surface ; at several inches' depth the soil may be reasonably dry. Great improvement can be effected in these circumstances by systematic spiking with one of the machines now on the market for the purpose. The spikes should penetrate about 4 in. and on very wet places hand pricking will also be necessary. On heavy land it is customary to lay the ground over ashes, and if ponding takes place it may readily be relieved by forking to allow the water through. Worm activity in hockey pitches often causes a slippery surface, with the ball constantly picking up mud. De-worming is the first step to improvement in such circumstances, and sanding assists surface drainage.

The area between the 25 line and the goal, especially inside the striking circle, as well as the central bullying area, receives the maximum wear. When play finishes these parts must be renovated with seed after thorough raking to prepare a seed bed.

A dressing of fertilizer should be given to assist establishment. It is better not to attempt turfing since dry weather may result in serious cracking. Many grounds are sown with rye-grass, which does not give that fine-textured turf necessary for the best playing conditions, but if rye-grass is already present then leafy strains of this species should be included in the mixture for renovating the striking area. Otherwise non-rye grass mixtures are best for general use on first-class grounds.

Many schools and colleges use their hockey fields during the early part of the season for rugby or association football. This makes the provision of a good hockey surface difficult, but there may be no alternative, though it is unfortunate that the heavier games should not be played after the hockey season instead of before.

Occasional fertilizer treatment and regular mowing, followed by routine rolling in the growing season, will keep the surface in good condition. Many grounds are mown with heavy motor machines, but better results would be obtained by mowing with the triple type of machine thus enabling rolling to be better controlled.

Association and Rugby Football Pitches. The long playing season of more than two-thirds of the year, including preliminary practising periods, coupled with the fact that these games may be played in very wet conditions or following frost, results in very heavy wear and tear.

On professional association football grounds the wear is so great that there is little left at the end of the winter but a mere triangular patch of grass in each corner. Intensive renovation each spring is therefore necessary on such grounds, but the difficulty is that play does not cease until April, and as practising begins in August only May, June and July are left in which to effect recovery. Under these conditions rye-grass should form the main ingredient of the seeds mixture because it is the grass species able to establish itself most rapidly in the time available. In order to gain some time seed is often scattered on to the pitch before the end of the season, and thus trodden in. It is true that a percentage of this becomes established and starts growth before the major operation of renovation begins, but far better results are obtained by shallow forking to put the seed slightly below the playing surface. Whilst most clubs are

prepared to renovate their pitches at the end of the winter they often do so in a very haphazard manner, and the seed bed thus produced is so poor that establishment and growth of the grass is feeble. Thorough peg or even pitch-pole harrowing must be carried out, and followed by chain harrowing, if a seed bed is to be produced.

During the winter months occasional rolling becomes necessary and the surface often becomes wet and greasy through the puddling action of the feet. Under such conditions the moisture is retained on the surface even though the ground may be well drained. Regular routine spiking and sanding will do much to prolong the life of the pitch and give better winter conditions. Rolling in winter often follows immediately play finishes for the day. This must be done to guard against a sudden fall in temperature causing freezing in the uneven state, thus possibly jeopardizing the next game. After sanding the surface, important association matches are played even if the turf be frozen.

Common weeds of football grounds are knot-weed, which enjoys a hard surface, and broad-leaved plantain, common in the goal-mouths or in the wetter portion near the stand. Wet puddled ground left with a thin open sward in summer suits this weed. Hand picking and raking before mowing should be adopted for the knot-weed, while for the plantains, dressings of sulphate of ammonia and sulphate of iron are best.

A general fertilizer should be given each spring to assist establishment of the turf, and during the summer months the grass should be kept mown, though not keenly. It is now generally realized that allowing the grass to run up for hay gives inferior results, and it is better to give an occasional topping.

The introduction of spiking into ground upkeep programmes is one of the most striking developments of recent years, and many clubs can testify to the prolonged life of the pitch and the better playing conditions that result.

Normally, less attention is devoted to grounds for rugby than those for association. Renovation with seeds at the end of the season may be necessary, but a much longer growth may be left to resist the wear and tear of the playing season. Occasional fertilizer treatment and topping with a reaper during the growing season are advisable. Light grazing may be carried out, but it is not advisable to take a hay crop. During the winter months when frost appears likely many clubs use a straw covering,

which involves an expenditure of anything up to £100 per annum on the straw and labour. The possibilities of using electric soil-heating cables would therefore seem worthy of investigation.

Where new football grounds are being made a level, true surface must be prepared. It must be well drained and sowing with rye-grass mixtures is usual.

Cricket Grounds. The upkeep of cricket grounds is a subject upon which many diverse views exist, and probably no two groundsmen will agree as to the best way of preparing and maintaining a wicket. The two distinct types of turf on cricket grounds are the wicket, which must be able to withstand wear and tear and give a true playing surface, and the out-field, which must be well mown and well rolled to give a fast surface. The wicket is the "holy of holies" to the groundsman, who often lavishes nearly all his personal care and attention on it. Here raking, close mowing, and rolling produce a result that is a mere apology for a turf. Indeed, maintenance of a first-class wicket is more a question of careful top-dressing and of discreet use of the roller than of turf upkeep.

Clay soils are most suited to good wickets, which should be laid on broken stone and ashes to ensure satisfactory drainage. The heavy soil rolls out into a smooth surface but on light soils it is necessary to incorporate a good deal of heavy soil and to marl in addition. Marling of wickets is an operation that should be carried out in the late autumn, and an annual dressing of from 1 to 2 lb. of marl per sq. yd. should be applied at this time of the year, and well worked into the surface by brushes and allowed to weather down. A dressing of loamy soil, 6 to 10 lb. per sq. yd., should be given before the dressing of marl, but a better plan is to mix the marl and soil together and apply them as a single dressing, which is then allowed to weather down. This procedure is preferable since it provides a less artificial wicket with bowler and batsman competing on more equal terms. No soft compost material should ever be used, and any tendency for a fibrous mat to form should be rigorously prevented. Matted turf must not be used for laying new wickets.

A general fertilizer is beneficial about the end of August, but if omitted, a winter dressing of raw bone meal may be applied with the soil and marl. In view of the heavy rolling and

the compact nature of the soil and marl on a wicket, forking should be carried out in autumn before the soil and marl treatment. De-worming is also necessary.

The final preparation of a wicket for a match begins about a week or 10 days before it is needed and involves mowing, raking, and further mowing to thin out and remove the top growth. More rolling should follow.

A week or ten days before the turf is required, some groundsmen prepare a mixture of 60 to 80 lb. of cow dung and 14 lb. of marl, mixed with 40 gal. of water ; this is allowed to stand 3 to 4 days, then sieved and applied to the surface after watering. When nearly dry the surface is rolled. This practice of "doping" is universally condemned.

During the playing season two or three dressings of general fertilizer may be given, or even one dressing followed by one or two dressings of sulphate of ammonia—which should always be spread with a carrier or given in solution, preceded by spike rolling. During the season all worn patches caused by the bowler or the fielders should be renovated, though the widest and deepest of these are best patched with turf, which must be kept well watered to resist drought. After a match the worst spots on the wicket should be pressed back with the foot and rolling should begin at the batsman's end so as to replace the small lump pushed up by the ball in the direction of the player. Worn places may receive a little soil and marl.

Some attention must always be paid to the practice wicket, which should receive occasional marling, top-dressing, regular mowing, and treatment with fertilizer to produce a surface approximating to that of the match wicket. The usual cricket roller weighs 10 to 15 cwt. and is capable of loading up to as much as 25 cwt. In recent years water-absorbing rollers have been introduced, and these are of great service when wet conditions are holding up play.

The prevalence of high scores and drawn matches in County and Test Cricket may in large measure be attributed to the fact that in recent years everything has been done for the batsman through the cumulative effect of excessive marling. Light marling to bind the pitch is undoubtedly helpful but heavy applications lead to a state of affairs favourable to the batsman and heart-breaking to the bowler. When dry the "shirt-front" sur-

face becomes a batsman's paradise, but when sodden it is lifeless for the bowler.

Fortunately for English cricket the opinion is gaining ground that wickets less artificial in character must be provided. The unfair bias against the bowler would then be removed, and the batsman would be required to exercise all his resources to circumvent an attack consisting of accurate length and controlled spin.

The ideal preparation of a county wicket should aim to give a pitch sufficiently durable to withstand two full days' play; it should give the bowler a chance on the third day; it should not be dangerous as far as personal injury is concerned; and, it should give "life" to the ball.

The wickets of to-day owe some of their artificiality to the excessive use of the heavy roller. When rolling was done by hand there was less chance of it being overdone, but nowadays mechanical rollers make light work of this operation. Probably 10 minutes' motor rolling is equivalent to 30 or 40 minutes' hand rolling. The packing aggravates the ill effects of over-marling, giving an impervious "soil" that delays recovery after rain.

The problem of upkeep of out-fields is made much more complicated by the regular use of the roller, which is necessary to produce a keen surface, so enabling the ball to travel evenly and fast to the boundary. The hardness created by this treatment can be relieved by systematic pricking, and attention must also be paid to weed destruction and worm control. A well-drained out-field is important, and ideally there should be a slope of not more than 1 in 85 from the square in every direction.

Nottingham marl for the treatment of wickets costs from 22*s*. to 26*s*. per cwt., free on rail, according to the fineness of grade.

Sports Grounds used all the Year round. At most schools and colleges, and on many club grounds, the fields are in use almost continuously all the year round—cricket in summer, football and hockey in winter. School grounds do receive some rest in the Christmas, Easter, and Summer vacations, but this is made up for by the very heavy use during term time, when each ground may have to carry several games a week. Where hockey or football grounds are transformed to cricket out-

fields for summer use, rapid renovation at the end of the winter season is necessary, all places that are worn being sown with seed and dressed with fertilizer. For this purpose an application of sulphate of ammonia with carrier produces rapid response. Before sowing takes place, however, uneven places must be well raked and harrowed, and even some soil added, the aim being to produce as good a seed bed as possible with a truer surface. At the end of the cricket season a general compound fertilizer should be given in order to establish the grass before winter play begins. Systematic spiking is also helpful at this point, and much can be done to improve conditions by de-worming and by attention to drainage.

In some districts lacrosse is the popular winter game, played on fields set aside for the purpose or upon cricket out-fields. The nature of the game does not involve so much cutting up of the ground as in hockey or football, and provided the turf is well drained it soon recovers at the end of the playing season. A certain amount of wear and tear takes place where the play is concentrated, and if considered necessary or desirable, renovation and fertilizer treatment may be given.

Kick-about-goal area. Immediately before the start of non-professional football, hockey and lacrosse matches there is often a good deal of practising round one or possibly both goals, thus placing an added burden on the most important parts of the ground. This should be prohibited and an area of the grounds set aside for the purpose and provided with the appropriate set of goal posts.

Chapter Thirty-six

Upkeep of Polo Grounds, Racecourses, and Other Turf Areas

Polo Grounds. It is essential that polo grounds should be laid in the direction of north to south in order to avoid playing into the setting sun which is not only dangerous but a disadvantage to the team playing towards it. Ideally the ground should slope gently on the line of the diagonal and this facilitates drainage. The rules of the Hurlingham Club Polo Committee require that a ground shall not exceed 300 yd. in length and 200 yd. in width if unboarded, but if boarded the width shall not exceed 160 yd. There must be a safety zone within about 30 yd. of the goal line and within 10 yd. of the boards. From this it will be seen that a full-sized unboarded polo ground requires a turf area 360 yd. long by 220 yd. wide, whilst if boarded the area necessary is 360 yd. long by 180 yd. wide. Ideally also a polo ground should be laid on a medium loam soil, because in wet conditions a clay soil is too slippery whilst in dry weather it becomes too hard. On the other hand, very sandy soils are dusty and may also become rather hard in dry seasons.

If the skill of players and the speed of ponies is to be exercised to the full a true and level surface is a necessity. Moreover, the turf should be tough and able to resist the hoof action, providing at the same time a sure foothold for the ponies. Any tendency for the turf to tear up in long strips must be avoided. The fact that polo is a spring and early summer game, played for 6 or 8 weeks, makes it unnecessary that the ground should be laid upon a cinder foundation. The latter part of the growing season is available for recuperation.

The eradication of weeds on polo grounds must receive attention because, even if the ground be level, its trueness may be destroyed by weeds preventing true running and causing a slippery surface. With broad-leaved plantains, for example, the ball may jump from 3 to 6 in. off the ground and if it is rolling slowly it may be turned off several inches.[66] Large patches of clover form a slippery surface for the ponies, which may fall heavily when attempting to turn. Daisies are also best eradicated, because they will cause a polo ball to jump and diverge from the line when it is running slowly. Similarly dandelion, yarrow, and buttercup are best eradicated before they have opportunity to increase.

Perhaps the most important aspect of maintenance of polo grounds is the cutting, and no more than 1 to 1½ in. of growth must ever be allowed; keen mowing with gang mowers is essential. The grass must be kept short because a long growth provides heavy play and is tiring to the players. Even after the end of the playing season it is desirable to keep the ground topped, and in the winter months an occasional run over is desirable. With gang mowers the clippings are returned but if possible machines with boxes should be used if the growth becomes excessive in June or July.

In conjunction with mowing, systematic rolling is necessary, using a wide agricultural roller. If earthworm casts are numerous rolling causes a slippery sealed surface, and therefore their eradication is essential if the best results are to be obtained. Whilst it is true that earthworms provide aeration, they cause an uneven surface and gang pricking machines will provide the aeration and relieve the compression caused by rolling.

It is useful to apply a general fertilizer in the early spring and again when the play ceases after the season. After the end of the playing season, too, renovation with seed may be required, and it is best to employ non-rye grass mixtures, harrowing the seed in and lightly dressing with soil. The provision of turf nurseries for patching badly damaged portions, especially in front of the goal, is well worth while.

From these general points it should be possible to elaborate a system of management to suit most grounds.

Racecourses. The ideal turf for horse racing and training is that

[66] *Polo*, The Lonsdale Library, 1936, XXI, Ch. 26.

found on heaths and downs, where the mat-forming grasses, the bents and fescues, often aided by mat-grass and wavy hair-grass, have developed over a period of many years a thick springy layer of fibre. The sites for the older racecourses were undoubtedly chosen deliberately because of the nature of this turf, though no doubt accessibility was an auxiliary factor. The excellent springy turf found at Ascot, Newmarket, Doncaster, and on the downland racecourses, to mention a few instances, is of this matted type. The reason for its popularity for horse racing and training is that the springiness acts as a shock-absorbing layer between the hoof and the underlying soil. This type of turf drains well and there is little fear of harming the horses ; even those with doubtful legs can be kept exercised in dry weather. A course constructed on a medium soil is best because a very dry soil is apt to be dusty and a clay soil provides such hard going in dry periods that there is a greater chance of the horses' legs being damaged. In wet conditions clay soils are apt to be treacherous.

It is unfortunately a fact that on old-established racecourses much of the springy mat of fibre has been lost, either through wrong use of fertilizer or applications of lime, or both, and no doubt this loss has been assisted by the punching and tearing action of the hoofs, which tends to destroy such mat. On present-day courses it has therefore become the custom to leave a long growth of grass in order to give a shock-absorbing cushion instead of that formerly provided by the fibre below the surface. One problem requiring investigation in connexion with race-course upkeep is the retention of matted turf or its recovery where lost. Dressings of granulated peat are valuable in aiding mat formation. On many racecourses the grass is allowed to run up to hay, a practice that one may hope will gradually be abandoned, since it does not give that density of turf that is necessary for the best results. Better results are obtainable by using sets of triple mowers, horse or tractor drawn, mowing at a height of 2 to 3 in., later allowing the grass to grow longer immediately before a meeting. By this means a much denser turf is obtained with more shoots per unit area, and balance between the finer-leaved grasses and the coarser-leaved species is distributed by this means in favour of the former. On light sandy soils well-rotted dung may be used, and on heavy soils sanding is beneficial. On hurdle and steeplechase courses a

rather longer and more tufted turf is desirable. A proportion of cocksfoot may be used, but this grass should not be sown on courses used for flat racing since a more uniform and shorter mown turf is required.

In recent years the question of watering racecourses has been much to the fore, and early methods involved the application of water from a system of perforated pipes arranged around the rails. Unfortunately this may easily leave unwatered a strip of turf immediately adjoining the railings, thus giving harder going than on the part receiving the bulk of water. Better results can be obtained by a series of transverse sets of sprinklers laid across the track and moved periodically so as to cover the whole course with a uniform application. In addition, spiking should be adopted to facilitate the entry of such water and to open up the soil wherever it has a tendency to be poached through the pounding action of the hoofs.

After each race it is necessary that the turf torn up shall be replaced or the hoof-marks filled with sandy soil, and before races regular mowing with occasional rolling must be done to prepare the surface. Light spring fertilizer treatment, and even a light dressing of a nitrogenous fertilizer a few weeks before a race meeting will give good results.

Even going is the essential prerequisite for a successful race-track.

Turf on Made-up Land. In the neighbourhood of many towns, sports grounds have been laid out upon land made up of tippings of household and other refuse. Unless the tipping is carefully controlled, however, the results are poor, but on "controlled tippings" excellent swards may be produced. Perhaps the most notable example of "controlled tipping" in relation to the provision of playing fields occurs in the city of Bradford, where some 40 to 50 fields for private clubs and schools are under control. The district abounds in steeply-sloping or broken land, unsuitable for building, and which at comparatively low cost may be secured and converted into valuable recreation fields.

Before tipping commences any useful top spit is removed to one side, the refuse being then tipped in layers 6 ft. deep and in strips 36 ft. wide, with banks at an angle of 40 degrees. Vehicles deposit the refuse on the upper level just clear of the

front bank of each 36-ft. strip and so each layer gets well consolidated by the repeated passage of vehicles. Great care is necessary to bury soft materials at the lower levels, to flatten tins and bottles, and to bury paper, the surface being finally finished with ashes and gulley or road sweepings. On deep sites the building up continues in 6-ft. layers and this method of compression permits little spontaneous combustion, though the exposed ends of banks have been known to smoulder and to sink considerably.

Topping of the sites with at least 6 in. of soil or preferably more is necessary, after which seeding may follow. If turfing is to be done a little less soil is permissible but seed has been sown on only 2 in. of soil, with resultant failure. With good preparation, excellent turf can be formed, and in one instance where a cricket out-field was sown with a mixture of fine fescues and bents, the sward was as good, if not better, than many found on natural land.

At times, fields produced on controlled tips suffer in late summer and autumn from the occurrence of the toadstools of the Shaggy-cap fungus (*Coprinus comatus*). The caps of this fungus cause eruptions and upset the surface, and, worse still, as they ripen they change to an inky black mass that is most objectionable. On occasion and on only a few acres of land the time of one man is almost fully taken up for two or three weeks in the year, clearing away these caps by the barrowful. There is yet no known method of control.

Play Grounds. Most municipalities now provide play grounds for children, and these are usually in two areas, one exclusively for the use of infants up to 5 years, and the other for children of 5 or 6 up to 11 years. Unfortunately on many grounds near the centre of cities an attempt is made to produce turf, but the intensity of use makes the result most unsightly. Here it is much better to treat the surface with shale or tarmac rather than attempt to produce grass. In areas that are not so near to the centre of cities a turf made from mixtures containing rye-grass is best, and regular renovation must be carried out. Many play grounds are seriously neglected, with the result that bare places appear, particularly in the neighbourhood of apparatus such as slides, swings, and so on. Being placed in permanent positions the wear immediately around the apparatus is con-

siderable and therefore steps should be taken from time to time to prepare a seed bed and renovate. The turf on play grounds should not be allowed to become unduly long, or the sward is unpleasantly wet for playing, and some degree of drainage is necessary to ensure that the maximum use is made with the minimum of wear and tear. An occasional general fertilizer will do much to counteract the damage to the grass.

Cemetery Turf. Cemetery grass has perhaps the least work of any turf sward and is probably the most neglected. In many cemeteries the grass is allowed to run up to hay and is then mown, but there are to-day so many implements for rapid mowing that there is little excuse for this custom provided an orderly and level lay-out of the plots is planned. There are available machines that will cut up to the coping edges of monuments, thus enabling the work to be accomplished rapidly. Keen mowing is not necessary, but it should be carried out regularly, and as this will lead eventually to some difficulties with weeds, occasional sulphate treatment to control daisies, or plantains, on heavily trodden paths, is necessary. Every cemetery should be provided with a turf nursery from which sods may be obtained for patching paths or sodding graves.

Playing Fields. It is perhaps appropriate in concluding this chapter to refer to the work of the National Playing Fields Association which has been responsible for some 2,500 new playing fields and grounds, grants-in-aid being largely derived from the Carnegie Trust, the King George Jubilee Trust, the King George Foundation and National Fitness Council. The Association believes that to provide reasonable facilities for both sexes and all ages the minimum area of playing fields per 1,000 of the population should not be less than 6 acres, of which 2 acres may consist of privately-owned land preserved for sport. It is to be hoped that municipalities will consider whether their recreational facilities are adequate to meet present and future needs of each community. Expenditure involving money from National sources, especially in view of the Youth movement, seems to be essential if the high cost of purchase, establishment and maintenance is to be met.

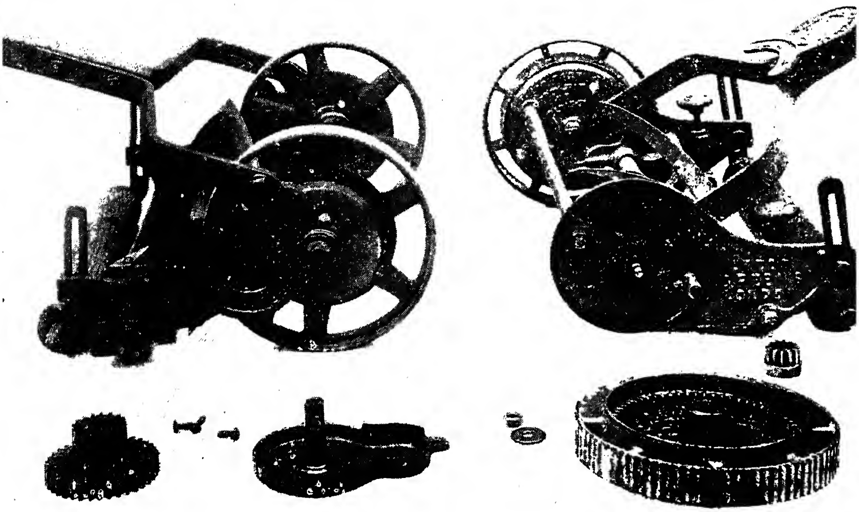


Fig. 34.—Two Types of side-wheel hand mower.

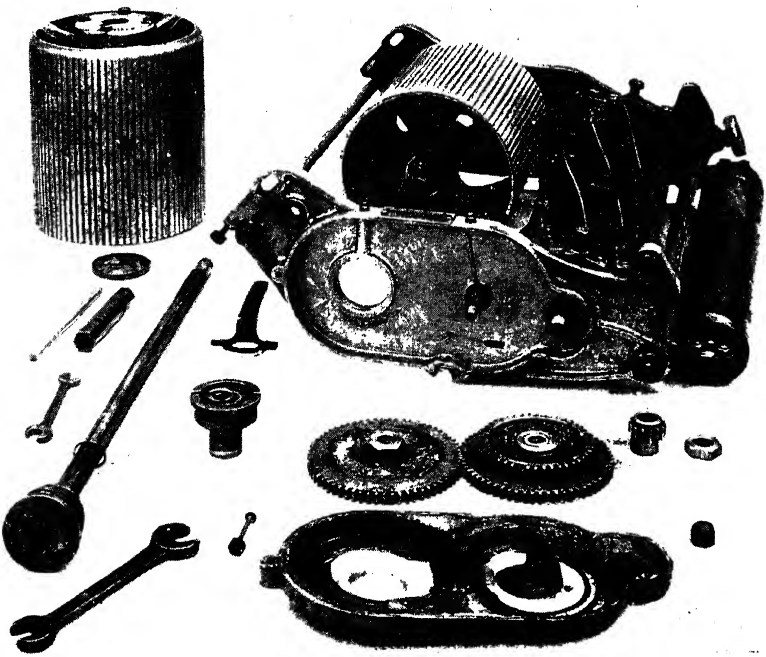


Fig. 35.—Typical Roller mower partially dismantled.

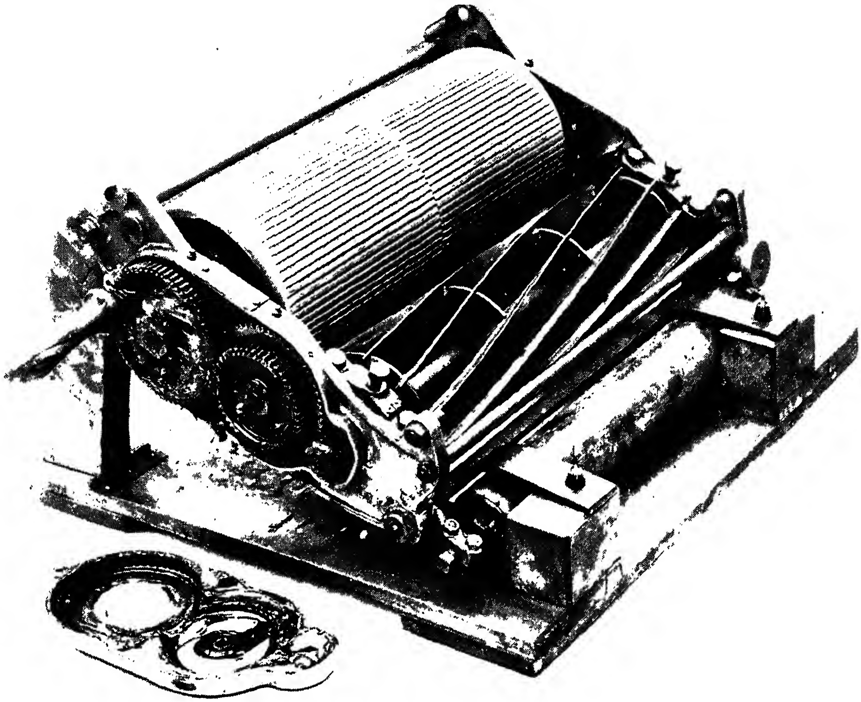


Fig. 36.—Roller mower mounted on stand for grinding-i

Chapter Thirty-seven

Establishment and Upkeep of Aerodromes

The choice of a site for an aerodrome must be largely governed by the land available near the town it is to serve, but it must be suitably placed for good communications and be free from obstructions outside the area. Ideally the land should be a light to medium loam and with a gentle fall and provision for the disposal of drainage water. If the soil is too sandy, it will not resist the rush of air from the air-screws and treatment with heavier soil becomes necessary. On the other hand, very heavy soil usually results in drainage problems and a soft muddy surface.

Landing grounds are usually made from pasture or arable land though at times heath or parkland turf has been used. It is very seldom that the 100 acres minimum for an aerodrome requires no constructional work; much less can an area of 300 acres such as necessary for a busy air port with facilities for taking off and landing of all classes of passenger liners and freight planes, be found in a condition ready for immediate use. In preparing a new ground extensive levelling may be required, involving the transport of large quantities of earth. Slopes up to 1 in 80 are permissible but steeper gradients require reduction. After ploughing, small undulations of 8 to 9 in. can be smoothed out by mechanical grading machines but in doing this exposure of the sub-soil must be avoided. Where it comes to the surface it must be dug out and top-spit applied. Sometimes levelling can be done by merely adding soil to depressions, leaving the higher portions untouched.

The drainage of aerodromes is of paramount importance, and many of them suffer very severely in wet weather from water-logging or even ponding on the surface, a condition that

makes pilots shy of landing owing to the treacherous surface. Special attention must always be devoted to ensuring adequate drainage of heavy land. If the soil is porous an elementary scheme is all that is necessary. Very often on old pastures there are ditches and hedgerows, and after the hedges and trees have been dragged out it is possible to use the ditches as the skeleton of an adequate drainage system, to which laterals may be taken. Thorough drainage is most important in the neighbourhood of the buildings and tarmac apron, because wear and tear is concentrated here. Old pastures taken over for landing ground may be very much pitted and broken by the feet of stock and often the use of a roller weighing 13 to 15 tons will effect sufficient improvement, but sometimes peg or even pitch-pole harrowing may be necessary to prepare the surface.

Cultivation is best carried out by steam ploughing or tractor ploughing, followed by harrowing, flat rolling, and Cambridge rolling to prepare the seed bed. In carrying out ploughing it is advantageous to break the sub-soil, but whatever is done the aim should be a truly level surface, and experience has shown that a smooth surface is the key to minimum damage by tail skids. Before sowing it is important that the land should be treated with artificials, and organic matter should be worked in, unless verbal inquiry indicates the soil to be in "good heart". When there is doubt advice should be sought.

Before discussing suitable grass species, it may be best to say something of the requirements of an aerodrome sward. Trueness has been mentioned, but the turf must also be sufficiently strong to resist the constant traffic of lorries and cars, and of the tearing of the skids. It must be strong enough to withstand the friction from pneumatic-tyred landing wheels to which brakes are being applied. Smoothness without jarring means a surface uniformly firm, free from hard and soft spots, and with a cushion of grass. The sward must not be too long, because if it gets out of hand it becomes tussocky and consequently uneven. On the other hand, a fine sparse growth provides a surface that is non-resilient and jars the plane on landing. Although it may be of secondary importance, the turf should be pleasing in appearance and of good colour. It should also be drought-resistant.

Grasses capable of forming a thick cushion are required. On lighter land non-rye grass mixtures are best. They should con-

tain crested dog's-tail, bent and the fescues, as well as smooth-stalked meadow-grass. About 1 to 1½ cwt. of seed per acre is usually sown. For heavier soils, or where less money is available, rye-grass mixtures should be used, most of the rye-grass being included as the indigenous type with a background of bent, fescue and rough-stalked meadow-grass. Although rye-grass mixtures are more costly to maintain, they are nevertheless frequently used for establishing new grounds. In both types of mixture it is usual and advantageous to include some 10 per cent by weight of yarrow seed, though its main value is on light soils for binding it by means of its tough underground rhizomes. Yarrow has the disadvantage of losing leaf in the winter but as a rapid colonizer it is valuable. The possibilities of creeping bent, which would presumably be helpful in colonizing bare areas, do not appear to have been explored. The *Cynodons*, which are creeping in habit, have been extensively used for making aerodrome swards in tropical countries.

Clover is best omitted from the seeds mixture because it provides a slippery surface when wet and dies back in the winter months. No doubt it has valuable recuperative powers and contributes some nitrogen, but the aim should be to produce a ground that does not require the recuperative action of such a plant as clover.

Although reliance is being placed to an increasing extent upon non-grass runways at busy aerodromes experience will doubtless show in course of time that to withstand hard wear a class of turf approximating to a good golf fairway, and consisting mainly of the tough dwarf growing species (bents and fescues) with a well-developed resilient hard-wearing mat, will be the most desirable.

As regards maintenance, one important matter is the constant renovation and treatment of worn or bare places. If these are not treated they develop into deeper depressions eventually causing serious upset to the surface. Large scars should have soil added and be renovated with seed while on heavy soils sand should be incorporated.

In recent years the value of regular pricking has been realized and wide gang pricking machines are being extensively adopted because they help to counteract the compressing action that is necessary in producing a true surface, and they open the soil to allow surface moisture to penetrate. The sward must be kept

regularly mown. Mowing is normally carried out with 9-unit gang mowers, cutting a 22 ft. 6 in. swath, drawn by a caterpillar tractor. More recently there has been developed a specialised high-power wheeled tractor capable of drawing nine 30-in. units (mowing a width of 21 ft.) and covering at 20 miles per hour 368 acres per 8-hour day.

Attempts have been made to graze aerodromes at slack periods, but it is not advisable owing to the large area involved and the impossibility of managing the stock well enough to get even grazing. Apart from this a messy surface results.

On a number of aerodromes the grass on the margin of the ground is collected and dried to form grass feeding cake.

Occasional fertilizer treatment of aerodrome turf is essential, especially on the central portion, if the sward is to be kept in vigorous condition and provide a good cushion for landing. The possibilities of using granulated peat for assisting the cushioning effect do not appear to have been investigated.

Before a site for a landing ground is developed it must be approved by the Air Ministry, whose advice is given upon the choice and upon the removal of adjacent obstructions. The completed ground will only be licensed after the Air Ministry has passed it. One of the tests adopted is to drive over the sward an ordinary car at 20 miles an hour without a noticeable bump when the car is running. Although this proves the trueness of the surface it does not establish the resiliency.

Municipal aerodromes must show on the ground the name of the town in 6-ft. letters surrounded by a 100-ft. circle. This is done by rolling chalk into the prepared letters or by inserting in the turf whitened concrete letters.

SECTION V

TURF UPKEEP IN OTHER COUNTRIES

Chapter Thirty-eight

Turf Upkeep in Some Other Countries

Introductory. A brief outline of the developments in the scientific study of turf upkeep in other countries has already appeared in the introduction to this book. It will be remembered that the first recorded experimental work with lawn grasses began about 1885 in Connecticut, U.S.A., to be followed in 1890 by the laying down of turf plots in Rhode Island. Following this the United States Green Section was formed in 1924 and the establishment of the Board of Greenkeeping Research in Great Britain took place in 1929. Other countries were not slow to take up the investigation of turf problems, and New Zealand set up a Board of Greenkeeping Research in 1932, and various States in Australia are now conducting experiments and collating information. In South Africa the pioneer work has been done by Dr. C. M. Murray, whose activities, going back to 1904, provided the stimulus that led to the investigational work now in progress on a wider scale.

Published information based on the results of scientific investigations into turf growing in other countries is singularly scanty, except in the United States, where most state colleges have issued bulletins on turf production in their own districts. In addition, the bulletins of the Green Section and of such state colleges of agriculture as have conducted specialized experiments provide a mine of information about turf culture in the U.S.A. It is desirable, however, for the sake of overseas readers, to include in this section some general information on turf problems in other countries, based either upon available literature or upon information acquired by direct inquiry.

In studying the reports of experiments on turf grasses one

cannot help feeling that other countries are not labouring under the influence of traditional methods as we are in the home country, there is less reluctance to try new methods of upkeep, to experiment with new species and strains of grasses, and to devise better ways of controlling turf pests. It is further apparent that much of the scientific work in progress is mainly in relation to upkeep of turf for golf. Nevertheless the majority of it is applicable to ornamental lawns and sports grounds in general.

The most potent factor in growing grass for turf is the climate, especially the factors of rainfall and temperature. To a lesser extent the soil and topography determine the species of grass available, but the climate is of primary importance. The incidence of insect and fungal pests and the general difficulties encountered in intensive management of grass in turf swards are largely determined by climatic factors. We are fortunate in Great Britain in having a temperate climate with the rainfall fairly uniformly spread throughout the year, and these factors have made this country pre-eminently suited to growing grass. In other countries much wider extremes of temperature are encountered and the conditions are more variable throughout.

The influence of climate, mainly temperature, is clearly seen in the distribution of the bents and fescues on the one hand, and the Bermuda grasses (*Cynodon* spp.) on the other. Thus, approximately between latitude 35° N. and 35° S. *Cynodon* is the major turf species, whilst north and south of this belt bent and fescue provide satisfactory turf. The bent of the temperature zones is analogous in its habit of growth, soil requirement, and leaf-forming propensity to the *Cynodon* of tropical and sub-tropical countries.

The significance of *Cynodon* in turf production is so important that it may be well to give here the common names by which it is known in the different countries. Thus, in the United States the common name is Bermuda grass, in South Africa, Kweek, in Egypt, Neguil, in India, Doob, in Malay, Serangoon, and in Australia, Couch. *Cynodon*, like *Agrostis*, is very variable morphologically and physiologically, and is a summer grower able to tolerate heat. Normally it fails to resist cold, though some strains are able to tolerate slight frost. In summer it needs less water than *Agrostis* and it thrives best on heavy soils, making a dense turf.

As far as golf turf in tropical countries is concerned *Cynodon* unfortunately thrives best during the off-season, while in the cooler playing season the colour is apt to be poor.

New Zealand. It is perhaps appropriate that first place be given to the consideration of turf production in New Zealand since the climate in that country approximates broadly to conditions in Great Britain. In 1932 there was set up a Board of Greenkeeping Research, which in the course of five years has investigated some of the outstanding problems. Many of the results of investigational work carried out in New Zealand have been incorporated in the Annual Reports [67] of the Board and in occasional articles published by the research staff.

The climate in New Zealand is temperate over large areas, but in North Island summer droughts are common. Under these conditions sowing is best done in autumn, about the third week of March, just before the break up of the drought and before the winter commences. On the other hand, over large areas of South Island summer rainfall is well distributed and in these parts spring sowing is advisable. In the drier parts of South Island, however, autumn sowing is preferable but some three weeks earlier than in North Island.

From the published reports and papers of the New Zealand Board it may be stated that the general findings on the experimental plots are closely in line with those found at St. Ives. This is particularly so in regard to manurial treatments, in relation to which it has been shown that sulphate of ammonia and sulphate of iron are of great value in controlling weeds and maintaining pure swards of the finer grasses. The experiments have also shown that these treatments must be supplemented by dressings of phosphatic manures. Further work in New Zealand suggests that the nitrogen used on an established weed-free turf might profitably be applied in equal proportions of two forms, namely nitrate of soda and sulphate of ammonia. The experiments [68] have also shown that for sowing turf, New Zealand browntop and New Zealand Chewing's fescue may be relied upon under average conditions to produce a dense turf.

[67] *1st, 2nd, 3rd, 4th and 5th Reports of N.Z. Bd. of Green. Res., Palmerston North,* 1933, 1934, 1935, 1937, 1940.

[68] Madden, E. A.: *Garden Lawns and Playing Grounds,* Bull. No. 165, N.Z. Dept. 1935.

Again, the results are in line with those found in this country and the proportions used are usually 4 parts of browntop to 6 parts of Chewing's fescue.

The majority of the weeds encountered are the same as those found in Great Britain, though there are various species peculiar to New Zealand. As regards the control of weeds, sulphate of ammonia and sulphate of iron are effective on the majority, but pearlwort and chickweed have been found resistant, whilst Onehunga weed (*Soliva sessilis*) and pennyroyal (*Mentha pulegium*) are also in this class. Arsenic pentoxide [69] * is now recommended for use in New Zealand in controlling these weeds. Experiments have also shown its effectiveness in eradicating most turf weed species, but it has the disadvantage that a general browning of the lawn results and that renovation of the bare places, if the weeds were numerous, is invariably necessary. This is one reason why the method has not received quite so much attention in the home country as it warrants. When dilute solutions of the pentoxide are used a standard application for all strengths is 1 gal. to 20 sq. yd.

Onehunga weed is rapidly becoming a most serious turf pest in New Zealand but fortunately the arsenic pentoxide is effective at a dilution as low as 1 : 160 or 1 : 200 of water, used as an all-over spray.[70] At this dilution very little damage to the turf takes place. Pennyroyal, chickweed, pearlwort, hairy pennywort (*Hydrocotyle moschata*) and small soldier's button (*Cotula australis*) are eradicated with a 1 : 60 or 1 : 80 solution. Waxweed or shiny pennywort (*Hydrocotyle americana*) and Westport weed (*Cotula dioica*) † may be effectively destroyed by a 1 : 60 solution.

New Zealand, like all countries, has its share of soil pests, and as regards earthworms, they are dealt with on the same lines as in Great Britain. Little prominence is given, however, to mowrah meal as it is not often imported and copper sulphate is more frequently used. In some districts the grass grub

[69] Bruce Levy, E., and Madden, E. A.: *N.Z. Jour. Agric.*, 1931, **42,** 406.

* Arsenic pentoxide (As_2O_5) is the anhydride of arsenic acid ($H_3As_2O_4$) and when dissolved in water gives the arsenic acid. Arsenic acid is the most convenient form in which to obtain this poison in Great Britain, whilst in New Zealand it is best purchased as solid arsenic pentoxide.

[70] See *3rd Annual Report of N.Z. Bd. of Greenkeeping Research*, 1935.

† Both this species and *Cotula squalida* have been found invading lawns in Great Britain.

(*Odontria Zealandica*) is a serious pest of turf and is rather similar in habit to the garden chafer of Great Britain. The adult is on the wing in late October, November and December, and sometimes into January. It flies at dusk, the female burrowing into the turf to lay her eggs. The grubs live on the turf and by April and May maximum damage results. In colder weather the grubs remain quiescent until August when in the warmer weather they become active again. Pupation takes place in September and October. Temporary control may be obtained by injecting carbon bisulphide into the soil or by making holes and filling with the liquid, afterwards plugging to prevent its evaporation. Emulsions of carbon disulphide or coal-tar distillate have been effective for all-over treatment, while naphthalene may be used for treating newly-prepared ground. For permanent control lead arsenate should be used at ¾ oz. per sq. yd., applied with a carrier of sand or soil, whilst pre-treatment before sowing may be carried out with lead arsenate at twice this rate. A firm turf is more resistant, so that on light land, which is most commonly infested, consolidation is important.

In certain parts of the country subterranean grass caterpillars (*Porina* spp.) are common; they live underground, emerging on to the surface at night to feed. Control may be effective by watering the surface with a suspension of lead arsenate, 3 lb. to 50 gal., to which a spreader has been added. This coats the leaves with a fine film of the arsenate, so resulting in the caterpillars being poisoned. Poison baits made from bran and lead arsenate have also proved successful.

Wherever lawn management is on an intensive scale the sward is apt to suffer from fungal diseases, and turf in New Zealand is no exception. Three species have been isolated from diseased turf and described,[71] namely *Sclerotinia trifoliorum* Erikss., *Rhizoctonia solani* Kuhns, and *Corticium fuciforme* (Berk.) Wakef. The symptoms of the disease caused by the first-named fungus are circular patches, 6 to 8 in. in diameter, in which the turf first turns yellow, then brown and finally dies. The attack takes place in irregular areas. The second species causes the disease known as Large Brown Patch—a prevalent turf disease in the United States. It appears first as small circular brown

[71] Brien, R. M.: "Three fungi causing 'Brown patch' of Lawns in New Zealand," *N.Z. Jour. Agric.*, 1935, **51**, No. 3, 157.

areas 2 to 3 in. in diameter, which gradually increase in size. The third species, *C. fuciforme*, causing the complaint sometimes known in New Zealand as "Red-thread" disease, appears as light brown patches with the red coral-like fructifications of the fungus. The remedial measure recommended in New Zealand for all these species consists of watering with perchloride of mercury solution at the rate of 3 oz. to 50 gal. of water per 2,000 sq. ft. of lawn.

The general principles of lawn upkeep as far as mowing, top-dressing, fertilizer treatment and general management are concerned follow those adopted in Great Britain, already described in the earlier part of this book.

Australia. During recent years wide interest has developed in turf matters in the Commonwealth, and the efforts of the Research Boards in Victoria, Queensland and New South Wales are worthy of whole-hearted support, since it is their endeavour to place turf upkeep in Australia on a sounder and more exact basis.

The species of grass used for turf formation are *Cynodon dactylon*, known among Australians as Couch or Indian Couch, and Queensland Blue Couch (*Digitaria didactyla*), both summer grasses and a poor colour in winter; and browntop and creeping bent—winter grasses of good colour in the cold season. In addition Carpet grass (*Axonopus compressus*), Kikuyu grass (*Pennisetum clandestinum*), and Germiston grass (*Cynodon transvaalensis*), have been introduced into various parts. The first two are only of use in providing coarser turf.

In Queensland [72] greens are made almost exclusively of blue couch (*Digitaria*), but couch (*Cynodon*) is preferable for inland districts as it is more drought-resistant. Winter-growing grasses such as browntop or annual meadow-grass should be introduced for use in the winter months. It is problematical as to whether the introduction of bent into the Brisbane area and Coastal belt instead of blue couch is worth while, on account of the extra labour necessary for upkeep, though trials in highland districts are advised. Latitude 35° S. forms the approximate border-line between economic growing of bent turf to the south and couch turf to the north.[72, 73] At Fremantle,

[72] Bulletins Nos. 1, 2 and 3, Queensland Bd. Green Res., 1935, 1936.
[73] Bulletin No. 2, Victorian Golf Assoc. Res. Sect., 1936.

Adelaide, and Sydney, couch thrives better in summer than bent whilst in Melbourne bent does better than couch.

In Sydney [74a] the tendency is to replace couch turf with sowings of bent (*Agrostis*) because of its better winter qualities, provided that adequate water and a moisture-retaining soil can be prepared. A compromise may be effected by thoroughly scarifying the couch greens in autumn and sowing upon their surface 3 to 4 lb. of browntop (*A. tenuis*) per 1,000 sq. ft. The requirement in Australia is for a one-grass green, giving a perfectly uniform surface as far as colour and texture are concerned. The high summer temperatures and the need for heavy watering constitute the determining factors in deciding the species of use. Cooler conditions permit greater use of bent. Unless couch greens are well managed and regularly top-dressed "nap" formation may become serious. Bent greens may also develop "nap". Pricking and tubular forking to counteract "dry patch" and to facilitate water movement are important operations.

Many of the weeds common to turf in Great Britain are also encountered in Australia, for example, cat's-ear, dandelion, and white clover. Among the grasses, annual meadow-grass (*Poa annua*), or as it is known there, annual winter-grass, is frequent. *Paspalum dilatatum* (known in America as Crab Grass) is a common weed, and hand weeding is usual. Leguminous weeds are creeping tick clover (*Desmodium triflorum*), and suckling clover (*Trifolium dubium*). *Soliva sessilis*, a South American plant, common in New Zealand under the name of Onehunga weed, is known in Australia as JoJo or Bindii, and is controlled by spraying with arsenic pentoxide 1 : 160 to 1 : 200. Another weed species is Capeweed (*Cryptostemma calendulacea*), for eradicating which a mixture of 3 lb. sulphate of iron, 1 part sulphate of ammonia, 15 parts sand, has been found effective at 6 oz. per sq. yd.[74b] Another common weed is the South American plant known as Whitlow weed (*Paronychia brasiliana*). Comparative trials at Royal Sydney Golf Club, recorded by Walkerden ([74b]) showed good control with a 1 : 40 solution of arsenic pentoxide at 1 gallon per 100 sq. ft., especially when followed in 10 days with 3 lb. sulphate of ammonia and

[74a] Bulletins Nos. 1 and 2, N.S.W. Golf Council Res. Com., Sydney, 1932, 1933.

[74b] Walkerden, R. B.: The "Chilean Whitlow" Weed, *The Australian Greenkeeper*, I, No. 4, 1937.

$\frac{1}{2}$ lb. sulphate of iron per 1,000 sq. ft. Another successful treatment was by means of "Camellia" weed-killer (1 : 45 at 300–320 gal. per acre) followed in 5–7 days with a spray of Tractor Distillate, which was then ignited.

The main soil pests are earthworms, usually dealt with by copper sulphate, and the Tasmanian grass grub or web worm, which eats the foliage in patches. It may be controlled by means of a bait consisting of 7 lb. of bran and 1 lb. of Paris green, which is spread in a moist condition at the rate of $3\frac{1}{2}$ lb. to about 600 or 800 sq. yd. In addition, there is the white curl grub larva of the black beetle (*Pentodon australis*), which devours the grass roots and is active between December and April. Injection of carbon bisulphide is effective, whilst applications of lead arsenate, 5 lb. per 1,000 sq. ft. give good results.[75] Mole crickets (best destroyed by injecting carbon bisulphide into the turf) and a number of other soil insects cause damage at times. A Scarab beetle (*Aphodius tasmaniæ*) found in South Australian lawns has been successfully controlled using a spray of 7 lb. lead arsenate in 100 gal. water.

Among the fungal diseases, brown patch and dollarspot have been identified, and various strains of blue couch and bent are susceptible. Effective control may be obtained [76] by applying calomel at 3 oz. per 1,000 sq. ft., or at the same rate a mixture of equal parts by weight of calomel and perchloride of mercury, either being spread with 6 to 8 quarts of sand.

Federated Malay States. The production of grass for tennis courts, putting and bowling greens, as well as polo grounds, is now much better understood in Malay, and the use of various native and introduced species from other tropical countries has much extended to a range of grasses available for these types of turf. Perhaps the most commonly utilized grass is carpet grass (*Axonopus compressus*), a native of the West Indies but widely distributed through the Southern United States, and from Mexico to the Argentine and Chile. It is a perennial creeping species propagated by vegetative means and forms a dense turf. It is widely distributed through Malay, where it has been used for making lawns, playing fields, and more recently

[75] Bulletins Nos. 1 and 2, N.S.W. Golf Council Res. Com., Sydney, 1932, 1933.

[76] *The Australian Greenkeeper*, Sydney, 1936, I, Nos. 1–3; 1937, II, Nos. 1 and 2.

aerodromes. Bermuda grass, or Serangoon grass (*Cynodon dactylon*) is found in all parts of the peninsula, and is widely used for the production of fine turf on tennis courts and golf greens, but growing as fine turf it is not strong enough to resist the invasion of weeds and other often coarser grasses. Constant attention to weeding is necessary and therefore on large areas like polo grounds and aerodromes it is not suitable. Australian blue grass (*Digitaria didactyla*) may be used for fine turf, though it is more valuable in the hills of Malay. It requires careful attention, otherwise it is smothered by the native grasses and weeds. On sandy soils a useful species is *Zoysia pungens*, a dwarf, fine-leaved, tufted grass that forms a good turf with a stiffer blade than that from Bermuda grass. *Paspalum conjugatum* as well as love grass (*Chrysopogon aciculatus*) may be used for making lawns and playing fields.

The general principles involved in the preparation of greens for Malayan conditions conform to those found in Great Britain, but adequate drainage, both to remove surface water and to prevent water-logging, is perhaps the most important feature to bear in mind.

As regards fertilizer treatment, it has been found that regular dressings of sulphate of ammonia are desirable to encourage leaf growth, provided that the phosphate supply is maintained. The use of sulphate of ammonia and sulphate of iron is common for the control of weeds, and earthworm eradication is normally carried out with perchloride of mercury.

Various insect pests cause harm to turf, some of the caterpillar type being controlled by applying lead arsenate at 1½ lb. to 50 gal. of water; and white ants, or termites, are controlled mainly by means of fumigants. One method is to inject doses of paradichlorobenzene, or materials emitting hydrocyanic acid gas. At the Singapore Golf Club prolonged trials have indicated a method of destroying the white ants; this, though somewhat laborious, is very effective. Holes 18 in. apart and 2 ft. deep penetrating the burrows are made with a crowbar and these are plugged with grass. After a time the termites, if present, will soon commence to repair the damage, showing their presence when the holes are examined. If a run is discovered in this way, a cigarette tin full of carbon disulphide is poured in and ignited, the explosion forcing the flames and fumes into the tunnel and nests.

A list of publications dealing with the production of turf in Malay is given at the foot of the page.[77-82]

Egypt. The climatic conditions in Egypt are such as to demand constant watering or irrigation. The previous attempts to grow bent and fescue grass failed through the high temperatures experienced, and attention is now being concentrated upon the production of grass from strains of *Cynodon* known in Egypt as Neguil. As in other tropical climates it is very variable, and a suitable strain must be utilized. The turf is produced vegetatively by planting the runners in rows 6 in. apart, and it is used on polo grounds, golf greens, bowling greens, croquet lawns, racecourses, and cricket grounds.

Until recent years golf greens in Egypt were composed of sand, but latterly the better understanding of grass production has led to the substitution by *Cynodon* turf for many sand greens. The native type of *Cynodon*, or Beladi neguil, is now giving way in many places to improved imported strains of *Cynodon* from Uganda and still further south. The native strains can be retained for golf fairways. The imported strain not only stands the heat of the Egyptian climate but a few degrees of frost. Constant watering is necessary. Experiments have shown that routine dressings of Nile mud and sulphate of ammonia, supported by occasional phosphatic dressings, form the ideal treatment.

A common pest in greens in Egypt is the mole cricket, and recent work has shown that lead arsenate is an effective controlling agent if applied at 1 oz. per sq. yd. A barium fluosilicate bait has also proved satisfactory.

India. There is little published information on the production of turf in India, but an account by C. M. Hutchinson appears

[77] McNaughton, E. J.: *Turf Production and Maintenance*, Published by Messrs. Imperial Chemical Industries (Malaya) Ltd., 1934.

[78] Lambourne, J.: "A Preliminary Report on Carpet Grass," *Malayan Agric. Jour.*, 1924, XII, No. 12, 402.

[79] Spring, F. G.: *Lawn Grasses and their Treatment*, Agric. Bull. of the Federated Malay States, September, 1912, I, No. 2, 76.

[80] Corbett, G. H.: "Insect Pests in Golf Greens," *Mal. Agric. Jour.*, 1932, XX, No. 1, 34.

[81] Lambourne, J.: "Lawn Grasses and their Maintenance," *Mal. Agric. Jour.*, 1937, XXV, No. 1, 3.

[82] McNaughton, E. J.: "Turf Production and Maintenance", *Maha Magazine*, 1934, No. 2, 258.

in the *Agricultural Journal of India*, 1914 [83] in which experiments on the production of turf with native strains of *Cynodon*, called in India, Doob, are described. The grass is grown vegetatively on soil prepared by a process of foot puddling, followed by heavy applications of cow dung. The Doob grass grows rapidly and produces a continuous turf in a few months. The native strains of Doob are able to withstand the intense heat and the rainy periods. Doob requires a liberal supply of easily-assimilable nitrogen, and Hutchinson's experiments have shown that regular dressings of sulphate of ammonia, supported by applications of sand lead to a fine dense turf, relatively free from weeds. He also found that regular treatment with sulphate of ammonia hastened the conversion of a mixed sward to a pure sward of *Cynodon*, and the regular use of sulphate of ammonia for lawn purposes in India is advised for routine use. The rate may be $1\frac{3}{4}$ lb. of sulphate of ammonia per 100 sq. yd., but on weedy swards the rate may be doubled to effect weed control. The sand used must be sharp and clean and occasional use of the roller is recommended. Hutchinson's work indicates that the best response with the sulphate of ammonia is obtained in the cold weather at the beginning of November, when its action is more rapid than in the rainy period. He also found that the use of heavy amounts of phosphate strengthened rival grasses, a finding which is in line with observations at St. Ives, in connexion with bent greens, and in the Capetown District of South Africa, where Dr. Murray has consistently advocated the use of only minimum amounts of phosphate.

South Africa. The scientific study of turf culture in South Africa really dates from 1904 when Dr. C. M. Murray [84] first became interested in the establishment of grass greens at the Royal Cape Golf Club. His enthusiasm and claims have done much to encourage further work, not only in South Africa but in other countries. In recent years extensive work has been carried out by T. D. Hall and D. Meredith, of African Explosives and Industries, Ltd., whose published work should be consulted for detailed information on turf upkeep in South Africa. Further work has been carried out by S. D. Timson, of Salisbury.

South Africa has a great diversity of climatic and topographic

[83] Hutchinson, C. M.: "Turf," *Agric. Jour. of India*, 1914, IX, 366.
[84] Murray, C. M.: *Greenkeeping in South Africa*, Capetown, 1932.

conditions. For instance there are golf greens and bowling greens at all altitudes from sea level to 6,000 ft., and under rainfall conditions of less than 5 in. a year up to 60 in. in certain localities. Further, there are parts of the country where rainfall is confined almost entirely to the summer months, with a long cold dry winter, while in the Capetown districts there is a winter rainfall and a long hot dry summer. Between these two extremes is a part of the country where the rainfall is more or less distributed over the whole year. This wide range of climatic conditions makes turf culture in South Africa a complex problem. It is gratifying to find,[85] however, that in spite of the complexities the area known as the Reef conforms, as far as sports purposes are concerned, to the ideal recreational requirements laid down by Stapledon in his book *The Land, Now and To-morrow*, where he advocates 10 acres of turf per 1,000 inhabitants.

Turf upkeep in South Africa is further complicated by wide diversity of soil types, many having a low phosphate content, whilst low organic matter content often means that a soil readily becomes hard and dry. Much of the work in South Africa has been concerned with the selection and propagation of strains of grass suitable for fine turf production and capable of withstanding the extremes of temperature so often encountered. One of the best-known strains of *Cynodon* was selected by Dr. Murray and used for planting the Royal Cape Golf Course; it is now known as "Royal Cape" and specimens of it have been sent to almost all parts of the world for comparison with native strains.

Another type, now usually known as Florida grass, was isolated about 1908 near Johannesburg, whilst Bradley grass, which was isolated before 1910, is gaining favour. Other strains are Elgin upright, Douglas, Umgeni, Campbell, Elliott, Magennis, and many others named after the finders, or the places at which they were found. More recently T. D. Hall has made a special selection from the Germiston Golf Course, and experimental work with this type and others is being carried out through the co-operation of the Transvaal Golf Union and the University of Witwatersrand. Among other grasses being tested are various temperate grasses, species of *Paspalum* and *Digitaria*

[85] Hall, T. D.: "Opportunities for Relaxation and Recreation on the Mines," 1936, *S. A. Jour. Sci.*, XXXII, 438.

and much valuable work is emerging from these researches. Kikuyu grass (*Pennisetum clandestinum*) has much in its favour for sports grounds and aerodromes where rainfall or moisture supplies are adequate.

Insect damage to turf in South Africa is in some parts severe, and is often caused by two kinds of termite. One type attacks old leaf sheaths and stalks of the grass in situ and can be kept in check by dressings of arsenate of lead. The other type is a forager that cuts the grass stems and leaves, carrying them underground to the nests. Poison bait has been found effective for control. Another pest is the mole cricket, which can be controlled by dressings of lead arsenate or by the introduction of repellents and soil fumigants. Poison baits have also been found successful. The larva of a cockchafer beetle causes harm on some golf courses and arsenate of lead has been found satisfactory, as well as soil fumigants.

The work in connexion with fertilizer treatments [86] has been quite extensive and has shown conclusively the value of sulphate of ammonia and sulphate of iron for turf treatment, but it has also shown that for the summer rainfall areas dressings of phosphate and occasionally of lime are necessary to maintain fertility and give a vigorous weed-free turf. On the other hand, Dr. Murray's experiments in Cape Town * indicate for the winter rainfall area that the minimum of phosphate is desirable and must be associated with regular use of sulphate of ammonia and sulphate of iron. Regular dressings of nitrogenous fertilizers every 4 to 6 weeks during the growing season are required to maintain a vigorous even growth of turf.

Some of the many problems [87] in South Africa are the maintenance of the optimum phosphate supply in the soil, the augmentation of the organic matter content, and the selection of strains of *Cynodon*, capable of remaining green in winter and more resistant to cold weather. Another problem is that of a nap, and certain strains such as Florida grass are apt to form a nap to a marked extent. Some of the later improved strains, however, are less given to this habit of growth.

[86] Moses, D. (Meredith, D.): "Fertility and Soil Reaction in Turf Production," *S. A. Jour. Sci.*, 1934, XXXI, 288.

* See ref. 84, p. 271.

[87] Meredith, D.: "Turf Maintenance Problems in South Africa," *Jour. Bd. Green. Res.*, 1937, V, No. 17, 99.

In producing lawns or greens the vegetative method is almost invariably adopted.

Europe. There is an absence of published information about the upkeep of turf in the various parts of Europe. In the western countries conditions for growing turf are very similar to those in Great Britain, though they are subject to greater extremes of temperature and in summer water is more essential. As a result of examination of many samples from, or visits to, turf areas in Belgium, Czecho-Slovakia, Denmark, France, Germany, Holland, Italy, Luxemburg, Spain, Sweden, it appears that the bent and fescue grasses may be satisfactorily used, and that turf production in these countries is subject to much the same difficulties as those encountered in Great Britain. The establishment of new areas of turf by means of bent and fescue in these countries may therefore be carried out satisfactorily. For instance, the same diseases and weeds are commonly found.

In the central parts of Spain there are greater extremes of climate, though the establishment of turf with bents and fescues has been satisfactorily carried out. High temperatures may be experienced during the day, followed by bitterly cold nights, and the winter conditions are much harder. In the more southerly parts of Spain attempts are being made to produce turf from strains of *Cynodon* introduced from South Africa and Egypt, but here the difficulty is to obtain a sward capable of resisting the dry hot winds experienced in July and August from the Sahara.

The production of good grass in the Riviera also presents difficulties, partly owing to the climatic diversity and partly to the very much poorer depth of soil to be found. During the summer months continuous surface watering is necessary to save the turf from complete destruction through lack of rain and fierce sun, but it is possible, in spite of the difficulties, to establish turf from the usual grasses employed for turf formation in other European countries. In recent years attempts have been made to use the bulblets of *Poa bulbosa*, a grass found in abundance in the Mediterranean regions. This grass is at its best during the winter months, but dies away during summer. Another method is to establish rye-grass greens in the early autumn, these establishing quickly and providing a cover during the residential season. The study of strains of grasses for these

parts and the improvement of the soil conditions for grass growing are amongst the most promising lines for future development.

China and Japan. No literature dealing exclusively with lawn production in these countries has been found, though a number of references appear in some of the American publications.

In Japan the grass species most largely employed is Korean lawn grass (*Zoysia pungens Japonica*). Seed is produced in Japan and the turf formed is dense with a strong underground system of rhizomes. This species has also been used on the Gulf coast in the United States. Another species used is *Zoysia tenuifolia*, a fine-leaved species that forms a dense wiry turf.

From direct inquiry as to turf growing in the Shanghai area of China it would appear that the chief difficulty is the climate, since the district suffers from extremes of heat and cold. July and August are very hot, temperatures of 100° F. in the shade being common, while the rainfall is fairly regular, and the growth of grass is good. Towards the end of November, however, a general browning of the turf takes place, and December and January are very cold months, often with biting winds. Korean lawn grass imported from Japan is in process of being tried out on the Hungjao Golf Course and the latest reports indicate that it has a value for turf production in the Shanghai area. Trials with bent and fescue species on the Hungjao Golf Course failed completely.

The commonest species of grass used for lawns in China is Centipede grass (*Eremochloa ophiuroides* (Munro) Hack.), a dwarf-growing and intensively stoloniferous plant. Perhaps the commonest turf weed in Shanghai is Crab grass (*Digitaria ischæmum*), an annual summer species that invades turf rapidly, causing a great deal of labour to effect its removal.

United States of America. In such a wide area there are naturally big climatic differences, but rainfall and evaporation are the principal ones, and these largely determine the species of use in the different parts. It may be of interest to refer briefly to some of the diverse climatic conditions encountered in this vast country. Broadly speaking, and especially in regard to golf courses, the turf maintenance is on a much higher plane

than in this country. More labour is used, more fertilizers, and the general equipment is on a more liberal footing.

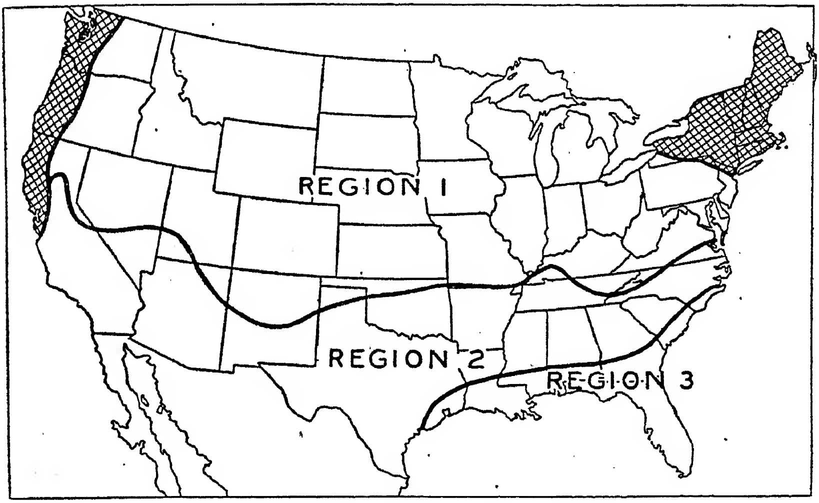
In most parts evaporation is relatively high and artificial watering is generally necessary—indeed, in some parts grass cannot be grown without it. Along the Pacific coast the total rainfall is low, most of it coming in the winter months. For example, at Los Angeles, the rainfall is 14·9 in. and about 60 per cent of it comes in the three winter months; there is less than 1 in. for the three summer months. Normally there is no rainfall from May to September, and evaporation is high, so that liberal sprinkling is essential.

At Denver, on the eastern slope of the mountains, the annual rainfall is similar, 14·1 in., but the distribution is the opposite, most of the rain coming in the growing season while the winters are cold and dry. Near the cities of Oklahoma and Kansas, the yearly rainfall amounts to over 30 in., and most of it is in the growing season, so assisting upkeep, but as evaporation is high, irrigation becomes essential. Throughout the middle-western territory the average rainfall may be as much as 48 in., fairly uniformly distributed throughout the year, but temperatures are high and dry winds absorb the moisture. In the eastern states the water requirements for turf are less than in the western, though provision for watering is now generally considered essential.

From the point of view of the suitability of the grasses an important line of demarcation is approximately 35° to 38° N.; north of this line, bent, fescue and Kentucky blue grass will thrive, whilst south of it is the Bermuda grass country. The position may best be understood if the United States is divided into three regions, as shown in the diagram [88] (Text Fig. C). In the first region Kentucky blue grass (*Poa pratensis*) has no superior for general use as a lawn grass, and it may in suitable soil be sown alone with good results. Where the soil is acid, however, the bent grasses should be used, since the Kentucky blue grass would not survive. Soils suited to bent are usual in parts of New York, in the New England States, along the Pacific coast of Oregon, in Washington and Northern California (shaded portion of diagram). In these areas the bent grasses, browntop, creeping bent and velvet bent are domin-

[88] Westover, H. L., and Enlow, C. R.: *Planting and Care of Lawns*, Bull. No. 1677, U.S. Dept. of Agric., 1931.

antly used, and the creeping species are produced vegetatively from stolons. Whilst the fescues may be used in conjunction with the bents on the acid soils they do not survive well under the influence of close mowing. In Region 2 Bermuda grass is most suitable, though at higher altitudes Kentucky blue grass does well. The Bermuda turf may be obtained from seed or prepared vegetatively; the chief objection to this species is that it dies down in winter and develops a poor colour. This poor winter condition is frequently overcome by raking in the fall and sowing with Italian rye-grass upon the Bermuda sward; it provides a good winter cover, dying away in the spring and



Text Fig. C.—Map showing regions of the United States where various lawn grasses succeed best. (From U.S. Dept. of Agric. Bul., 1677.)

giving place again to the Bermuda. In parts of Western Kansas[89] buffalo grass (*Bulbilis dactyloides*) is used, and in this area it tolerates drought, requires very little watering, and produces a dense turf.

In Region 3 most of the lawns are produced from single species.[90] Bermuda grass and St. Lucie grass (*Cynodon dactylon* var. *St. Lucie*) are used for the dry areas where the soil is heavy, while carpet grass (*Axonopus compressus*) is especially desirable

[89] Enlow, C. R., and Stokes, W. E.: *Lawns in Florida*, Bull. No. 209, Univ. of Florida, 1929.

[90] Zahnley, J. W., and Quinlan, L. R.: *Lawns in Kansas*, Bull. No. 267, Kansas State Coll. of Agric., 1934.

on moist soils. One of the most outstanding grasses is centipede grass (*Eremochloa ophiuroides*) produced vegetatively. It was originally introduced from China. St. Augustine grass (*Stenotaphrum secondatum*) has no equal in Florida and in the southern states as a shade grass. It grows equally well in the sun, and if well watered and supplied with nitrogen forms a good turf. In Region 3 (Florida) experiments have been done with Australian blue couch and species of *Zoysia*. *Z. tenuifolia*, Mascarene grass, sometimes called Korean velvet grass or Japanese velvet grass, produces a very fine textured turf and has been grown for a number of years in Florida and California. *Z. japonica* or Korean lawn grass is coarser than the above but hardier, while the third species *Z. matrella*, Manila grass, is intermediate in texture.

The production of turf for air ports has received some attention, and in Region 1 mixtures of Kentucky blue grass with redtop and rye-grass, with small proportions of fescue, are used, whilst in Regions 2 and 3 species suitable for lawns are also useful. Similarly for polo grounds and athletic grounds the species utilized for lawns may be planted. Comparative trials by North and Odland [91] at Rhode Island Experiment Station indicate a high quality rating for various strains of velvet bent and browntop, these coming out higher in quality than the creeping bents from seeds or stolons. Work by De France [92] has shown that for athletic fields in Rhode Island a mixture of 2 lb. Chewing's fescue, 1 lb. browntop, 1 lb. Kentucky blue grass and 2 lb. short seeded perennial rye-grass, per 1,000 sq. ft. gave good results. The incorporation of peat into the soil was found advantageous.

In the United States much attention has been devoted to experiments with fertilizers for turf, and the published literature of the Rhode Island, New Jersey,[93] and other Experiment Stations should be consulted. A satisfactory and quick-acting fertilizer consists of 3 parts cotton seed meal and 1 part of sulphate of ammonia, or dried sewage sludge may be used instead of the meal, and the application should be at the rate of

[91] North, H. F. A., and Odland, T. E.: *Putting Green Grasses and their Management*, Bull. No. 245, Rhode Island Agric. Exp. Sta., 1934.

[92] De France, J. A.: "A Comparison of Grasses for Athletic Fields and the Effect on the Turf of Peat incorporated with the Soil," *Proc. Amer. Soc. for Hortic. Sci.*, 941, **39**, 433.

[93] Sprague, H. B., and Evaul, E. E.: *Experiments with Turf Grasses in New Jersey*, Bull. No. 497, New Jersey Agric. Exp. Sta., 1930.

15 to 20 lb. per 1,000 sq. ft. A usual complete fertilizer for application to turf in the United States is one containing 6 per cent of nitrogen, 8 per cent of phosphoric acid, and 4 per cent of potash. The use of compost is also advocated, especially on creeping bent greens. The experiments to which reference has already been made earlier in this book show the value of fertilizers that leave an acid residue in the soil for maintaining turf in weed-free condition, and in eradicating weeds should they establish. The vastness of the country implies great variability in conditions and local or State literature should be consulted. Only a few references can be included here.

Many of the weed species encountered in Great Britain are also common in the United States,[94, 95] but perhaps the most troublesome are Crab grass, dandelion, various plantains and chickweeds. Of these crab grass is very often a serious pest, and under high temperatures and excessive moisture will invade a lawn rapidly, smother the desirable grasses at an astonishing rate. On relatively small areas hand weeding is best, but for large areas six weekly applications of a ½ per cent solution of sodium chlorate used at 10 gal. per 1,000 sq. ft. has been found effective.[96] Application should start when the plants are young. Since thin, open closely mown turf favours the weed, the height of the blade should be raised and the turf dressed with a complete manure. Raking and cross mowing is helpful. Calcium and lead arsenates have been successfully used,[97] but rates of 15 lb. of the former and 25 lb. of the latter per 1,000 sq. ft. are necessary and damage to grass results.

As in Great Britain the sulphates of ammonia and iron are frequently used for weed control in the United States, but greater use has been made of arsenicals. Thus a single spray of sodium arsenite or arsenic acid at 3 to 4 oz. per 1,000 sq. ft. is often sufficient to destroy mat weeds,[95] but tap rooted weeds are more resistant and thus require individual treatment. Applications of calcium cyanamide at 2,000 lb. per acre have been

[94] Curtis, R. W., and De France, J. A.: *Lawns, Construction and Maintenance*, Bull. No. 296, Cornell Univ. Exten., 1934.

[95] Monteith, John, Jr.: *Weed Control in Turf*, Bull. 27, 55 Imp. Bur. of Pastures, etc., Aberystwyth, 1940.

[96] Welton, F. A., and Carroll, J. C.: *Control of Lawn Weeds and Renovation of Lawns*, Bull. 619, Ohio Agric. Expt. Sta., 1941.

[97] Welton, F. A., and Carroll, J. C.: "Crabgrass in Relation to Arsenicals," *J. Amer. Soc. Agron.*, 1938, **39,** 816.

successfully used against common lawn weeds.[98] The perennials were more resistant than the annuals and the grasses, including Cynodon, were not killed.

A very dilute sodium chlorate solution is advocated for spraying, but it is a treatment that requires very careful handling, or it may cause the death of considerable areas of turf.

A number of soil pests occur in lawns, and if not specially dealt with may do much damage.[99, 100] The commonest of these are the grubs of Japanese (*Popillia japonica*) and Asiatic (*Anomala orientalis*) beetles and other "white grubs", which feed on the roots of grasses and may cause severe damage if many are present. Damage usually shows in early fall. It has been found that where grub injury is threatened, powdered lead arsenate at 5 lb. to 1,000 sq. ft. is effective. Protection against the grubs may be maintained by annual applications of the arsenate.

The sod webworm (*Crambus* spp.) is also a common pest of turf, and an application of arsenate of lead at 2 lb. to 20 gal. of water applied to 1,000 sq. ft. is one method of treatment, while spraying with pyrethrum extracts and kerosene emulsions has in some instances given better results than the arsenate. Another common insect found in turf, particularly in hot seasons, is the chinch bug (*Blissus leucopterus*) which causes damage by sucking out plant juices from the crowns of the grasses. Recent work indicates that an application of derris dust is the easiest method of control. It should be uniformly dusted over the infested areas at 6 to 10 lb. per 1,000 sq. ft. Nicotine dust has also been tried with a fair degree of success.

As regards earthworm control, a common method is by means of arsenate of lead, 10 lb. per 1,000 sq. ft., increasing the rate on heavy or clay soil, while perchloride of mercury is often used as an eradicant. Annual applications of arsenate at half the above rate are advocated to ensure continued immunity.

[98] Starkie, D. G.: "Control of Weeds in Lawns with Calcium Cyanamide," *J. Amer. Soc. Agron.*, 1937, **29** 803.

[99] Hamilton, C. C.: *The Control of Insect Pests of Lawns and Golf Courses*, Circ. No. 347, New Jersey Agric. Expt. Sta., 1935.

[100] Fleming, W. E.: *Preventing Injury from Japanese and Asiatic Beetle Larvæ to Turf in Parks and other Large Areas*, Circ. No. 403, U.S. Dept. Agric., 1936.

Fungal diseases [101] in the United States cause a great deal of damage, and fine turf may be almost destroyed overnight by an attack of brown patch caused by *Rhizoctonia solani*. Whilst Bordeaux fungicides are effective there is a danger of copper accumulating in the soil owing to repeated spraying, and therefore mixtures of perchloride of mercury and calomel are usually recommended. A common mixture is one-third perchloride to two-thirds of calomel at the rate of 3 oz. per 1,000 sq. ft. Small brown patch or dollarspot caused by *Sclerotinia homœocarpa* is also prevalent, and for this calomel at 3 oz. per 1,000 sq. ft. is a normal recommendation. Greens may also be much damaged by snow mould, against which the mercury compounds are usually recommended in the United States. Recently a new non-mercury fungicide, "Thiosan", containing tetra-methyl thiuramdisulphide has been tested against both dollarspot and brown patch. It was found successful as a preventative when used at 3 oz. per 1,000 sq. ft. every 7–10 days.

Canada. The general principles for turf upkeep as described in the earlier chapters of this book may be followed fairly closely for conditions in Canada.[102] A most important point in establishing lawns and greens is good surface drainage, and a free outlet for moisture must be assured, otherwise much grass will be lost through water-logging. A general principle advocated in Canada, as in this country, is modification of the soil to suit the grasses, and a common species used is Kentucky blue grass. This species is able to tolerate a wide range of soil and climatic conditions, and is reasonably resistant to drought. It is therefore used for ordinary lawns and golf fairways, but cannot be used for greens since it fails to stand the close cutting. For second-class lawns, mixtures containing Kentucky blue grass, redtop and browntop are utilized, whilst for the finest turf browntop and various strains of creeping bent are used; some of the latter, for example Washington and Metropolitan, have been introduced from the United States. Turf formation is commonly carried out vegetatively. Canada blue grass (*Poa compressa*) is sometimes advised, but it is only suited to the poorer soils, and

[101] Monteith, Junr., John, and Dahl, A. S.: *Turf Diseases and their Control*, Bull. U.S. Golf Assoc. (Green Section), 1932, **12**, No. 4, 87.

[102] Hamilton, R. I., Dimmock, F., and Clarke, S. E.: *Turf for Sports Use*, Bull. No. 148, Dom. of Canada Dept. of Agric., 1931.

it is best for fine turf to improve the soil and use better species. Canada blue grass, however, is suitable for coarse grass such as is found in the rough on a golf course.

The general principles of fertilizer treatment as laid down in earlier chapters may be followed. Occasional seasonal dressings of sulphate of ammonia are advised.

Most of the common turf weeds of Great Britain are also found in Canada, and Woods [103] has prepared a useful summary of his findings. Two September sprays (3 weeks between) of a 10 per cent copper sulphate solution at 1 gal. per 250 sq. ft. has controlled catsear. Stove oil at 1 gal. per 200 sq. ft. was found effective for plantain and partially so for dandelion and catsear when given in the fall. The oil did not control mouse-ear chickweed and pearlwort for which a mixture of 3 parts calcined sulphate of iron, 2 parts sulphate of ammonia and 15 parts dry sand sprinkled on the plant clusters is recommended. Care is needed not to over treat, otherwise serious scars result. Promising results have been obtained with sodium arsenite sprays (½ oz. to 1 gal. per 250 sq. ft.) especially for mouse-ear chickweed. Large scale use of sodium arsenite and arsenic acid at Toronto Golf Club has given highly satisfactory results in controlling dandelion, knotweed, clover, plantain, and chickweed, on the fairways.

A common turf disease in Canada is snow mould (*Fusarium* sp.), the symptoms of which are dead areas of turf of various shapes and sizes as the snow melts in early spring. According to Broadfoot,[104] who has carried out experimental work, as long as no less than 4 oz. of calomel and corrosive sublimate in any proportion is applied per 1,000 sq. ft., control will be obtained. As a general recommendation a mixture of equal parts of these two forms of mercury is advised.

[103] Woods, J. J.: "Chemical Weed Control in Lawns," *Sci. Agric.*, 1942, **22,** 356.
[104] Broadfoot, W. C.: "Experiments on the Chemical Control of Snow Mould of Turf in Alberta," *Sci. Agric.*, 1936, **16,** No. 11, 615, and *Jour. Bd. Green. Res.*, 1938, V, No. 18, 182.

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The Greenkeeper's Reporter—bi-monthly organ of the Greenkeeping Superintendents Assoc. published from St. Charles, Ill.

Parks, Golf Courses and Sports Grounds—published monthly by Clarke & Hunter, 92 Victoria Street, London, S.W.1.

Bulletin of the United States Golf Association (Green Section), from Box 73, Benjamin Franklin Station, Washington, D.C., published from 1921 to 1933 and now superseded by *Turf Culture* and *Timely Turf Topics*.

Journal of the Board of Greenkeeping Research—published half-yearly from St. Ives Research Station, Bingley, Yorkshire.

Appendix One

Showing the Composition of Fertilizers and Fertilizing Materials

	Total Nitrogen	Total Phosphoric Acid	Water-soluble Phosphoric Acid	Total Potash
INORGANIC ARTIFICIAL FERTILIZERS.				
Nitrate of Soda (Chilean)	15·5 to 16·0	—	—	—
Nitrate of Potash (Chilean)	15·0	—	—	16·0
Nitrate of Potash (Synthetic)	12·0	—	—	40·0
Nitrate of Lime . .	13·0	—	—	—
Nitro-Chalk	15·5	—	—	—
Ammonium Nitrate . .	35·0	—	—	—
Ammonium Chloride .	25·5 to 26·0	—	—	—
Ammonium Sulphate .	20·6	—	—	—
Mono-Ammonium Phosphate	12·0 to 12·3	—	55·0	—
Calcium Cyanamide. .	20·6	—	—	—
Urea	46·0	—	—	—
Superphosphate of Lime	—	—	13·75 to 18·3	—
Ground Rock Phosphate	—	25·0 to 39·0	—	—
Basic Slag	—	8·0 to 18·5	—	—
Sulphate of Potash . .	—	—	—	48·0
Muriate of Potash . .	—	—	—	50·0
Potash Salts (30% High Grade)	—	—	—	30·0
Potash Salts (20% Low Grade)	—	—	—	20·0
Kainit	—	—	—	14·0
ORGANIC FERTILIZERS.				
Dried Blood	12·0 to 14·0	trace to 1·0	—	—
Hoof and Horn Meal .	12·0 to 14·0	—	—	—
Meat Meal	10·0 to 11·0	0·4	—	0·6
Meat and Bone Meal .	3·0 to 8·0	10·0 to 20·0	—	—
Bone Meal	3·0 to 5·0	20·0 to 22·0	—	—
Steamed Bone Meal . .	0·75 to 1·0	27·5 to 29·0	—	—
White Fish Meal . . .	9·9 to 10·0	9·0 to 10·0	—	1·0
Fish Guano	6·0 to 7·5	5·0 to 7·0	—	0·5 to 0·8
Peruvian Guano . . .	up to 18·0	6·0 to 25·0	—	2·0 to 6·0
Poultry Manure . . .	0·8 to 4·0	1·0 to 4·0	—	0·6 to 2·3

	Total Nitrogen	Total Phosphoric Acid	Water-soluble Phosphoric Acid	Total Potash
ORGANIC FERTILIZERS.				
Poultry Manure (Kiln Dried)	4·3	1·3	—	2·9
Fresh Farmyard Manure (with straw) . . .	0·39	0·18	—	0·45
Fresh Stable Manure (with straw) . . .	0·58	0·28	—	0·53
Fresh Cow Manure (with straw)	0·34	0·16	—	0·40
Finely Ground Peat . .	1·0	—	—	—
Sewage Sludge, Bradford Corporation . . .	2·5	0·3	—	trace
Seaweed	0·4 to 0·5	0·08 to 0·1	—	0·8 to 0·9
INDUSTRIAL BY-PRODUCTS				
Shoddy	5·0 to 14·0	—	—	—
Leather Waste . . .	6·5	—	—	—
Bone Charcoal . . .	1·5 to 2·0	28·0 to 35·0	—	—
Soot	2·0 to 11·0	—	—	—
Flue Dust	—	—	—	trace to 6·0
Kelp	—	—	—	15·0 to 20·0
Rape Meal	5·0 to 6·0	1·5 to 3·0	—	1·0 to 1·75
Castor Meal	4·0 to 6·0	1·5 to 2·0	—	1·5 to 2·0
Mowrah Meal . . .	2·45	2·75	—	2·5
Malt Culms	3·0 to 5·0	1·0	—	2·0
Spent Hops	3·0 to 4·0	1·0 to 1·5	—	trace to 1·0
Pomace	2·0 to 2·5	—	—	—
Distillery Residue . .	4·9	5·0	—	3·0
Cocoa Husk . . .	3·85	1·87	—	3·0

Appendix Two

Fertilizer Mixing Table

(*Taken from Ministry of Agriculture and Fisheries Bulletin No. 28.*)

O May be mixed.

: : May be mixed if applied quickly.

X Should not be mixed.

Note.—Dry conditions of mixing are assumed in this table.

	Sulphate of Ammonia	Nitro-Chalk	Nitrate of Soda	Calcium Cyanamide	Sulphate and Muriate of Potash	Potash Salt and Kainit †	Superphosphate	Basic Slag	Bone and Rock Phosphates *	Ammonium Phosphate	Carbonate of Lime	Oxide of Lime
Sulphate of Ammonia .	O	O	O	X	O	: :	O	X	O	O	: :	X
Nitro-Chalk	O	O	O	X	O	: :	: :	X	O	: :	O	X
Nitrate of Soda . . .	O	O	O	O	O	: :	: :	O	O	: :	O	O
Calcium Cyanamide . .	X	X	O	O	O	: :	X	O	O	X	O	O
Sulphate and Muriate of Potash	O	O	O	O	O	: :	O	O	O	O	O	O
Potash Salt and Kainit .	: :	: :	: :	: :	: :	O	: :	: :	: :	: :	: :	: :
Superphosphate . . .	O	: :	: :	X	O	: :	O	X	: :	O	: :	X
Basic Slag	X	X	O	O	O	: :	X	O	O	X	O	O
Bone and Rock Phosphates*	O	O	O	O	O	: :	: :	O	O	: :	O	O
Ammonium Phosphate .	O	: :	: :	X	O	: :	O	X	: :	O	: :	X
Carbonate of Lime . .	: :	O	O	O	O	: :	: :	O	O	: :	O	O
Oxide of Lime	X	X	O	O	O	: :	X	O	O	X	O	O

* Except dissolved bones should be treated as Superphosphate.

† The mixtures in this column can be kept for a time if they are dry.

Appendix Three

Dimensions of Grounds, Etc.

ASSOCIATION FOOTBALL.

Ground.—Minimum, 100 yd. × 50 yd.
Maximum, 130 yd. × 100 yd.

ATHLETICS.

Two parallel lines 80 yd. long and 265 ft. 2 in. apart joined by a semi-circle with a radius of 132 ft. 7 in., will produce a track of four laps to the mile by measuring one foot outside these lines.

Similarly:

Length of Parallels	*Width Apart*		*Radius of Semicircle*	
Yd.	*Ft.*	*in.*	*Ft.*	*in.*
90	246	3·379	123	1·69
100	227	0	113	6
110	207	11	103	11·5
120	188	10	94	5
130	169	9	84	10·5
140	150	8	75	4

BASKET BALL.

Court.—80 ft. to 90 ft. long × 40 ft. to 50 ft. wide.

BOWLS.

42 yd. square maximum, 35 yd. minimum, inside ditch. *Rinks:* Width 21 ft. maximum, 19 ft. minimum.

CRICKET PITCH.

Length of pitch 22 yd.

CROQUET LAWN.

Full size 35 yd. × 28 yd.

HOCKEY.

Ground.—100 yd. × 55 to 60 yd.

LAWN TENNIS.

Court.—78 ft. × 36 ft. (single 27 ft.) Allowing for run back, etc., the following measurements are given as a guide:

	Maximum	*Minimum*
Grass	110 ft. × 55 ft.	100 ft. × 52 ft.
Hard	120 ft. × 60 ft.	116 ft. × 56 ft.

POLO.

Ground.—Length not to exceed 300 yd.; breadth not to exceed 200 yd. if unboarded, 160 yd. if boarded.

RUGBY FOOTBALL.

Ground.—Not exceeding, and as near as practicable, 110 yd. long and 75 yd. broad, with a maximum of 25 yd. at each end for "dead-ball" line.

HOW TO FIND A RIGHT ANGLE.

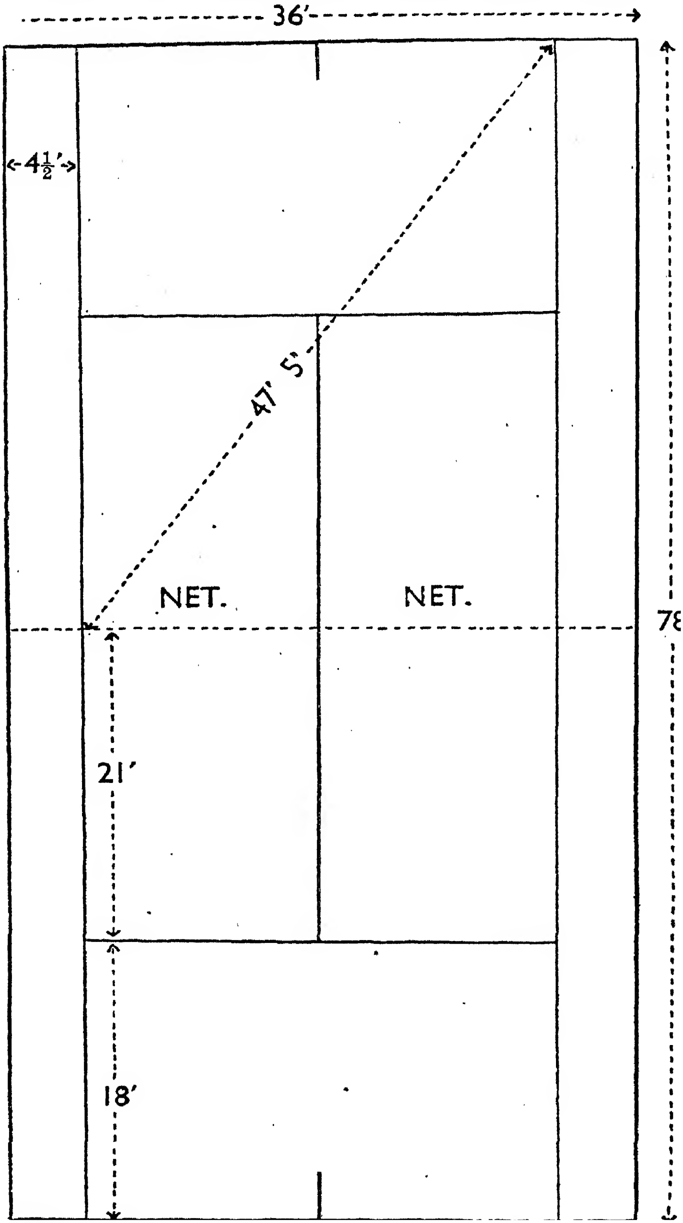
A piece of metal (or wood) 3 ft. in length, with cords attached at each end, one 4 ft. long, the other 5 ft.

The right angle is obtained by placing the metal (or wood) on the ground and driving in a pin where the strings meet.

Appendix Four

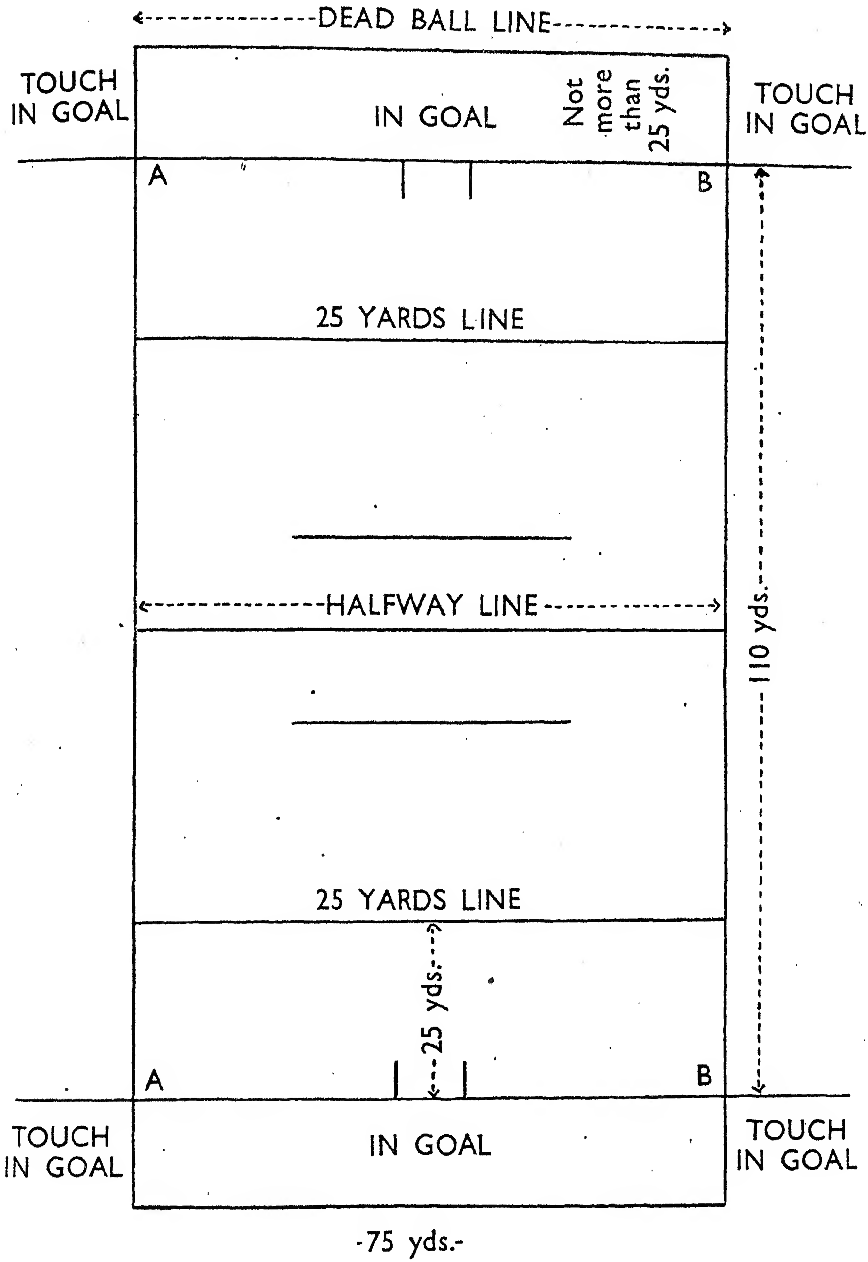
Diagrams of Sports Grounds

Diagram of Ground marked out for Lawn Tennis



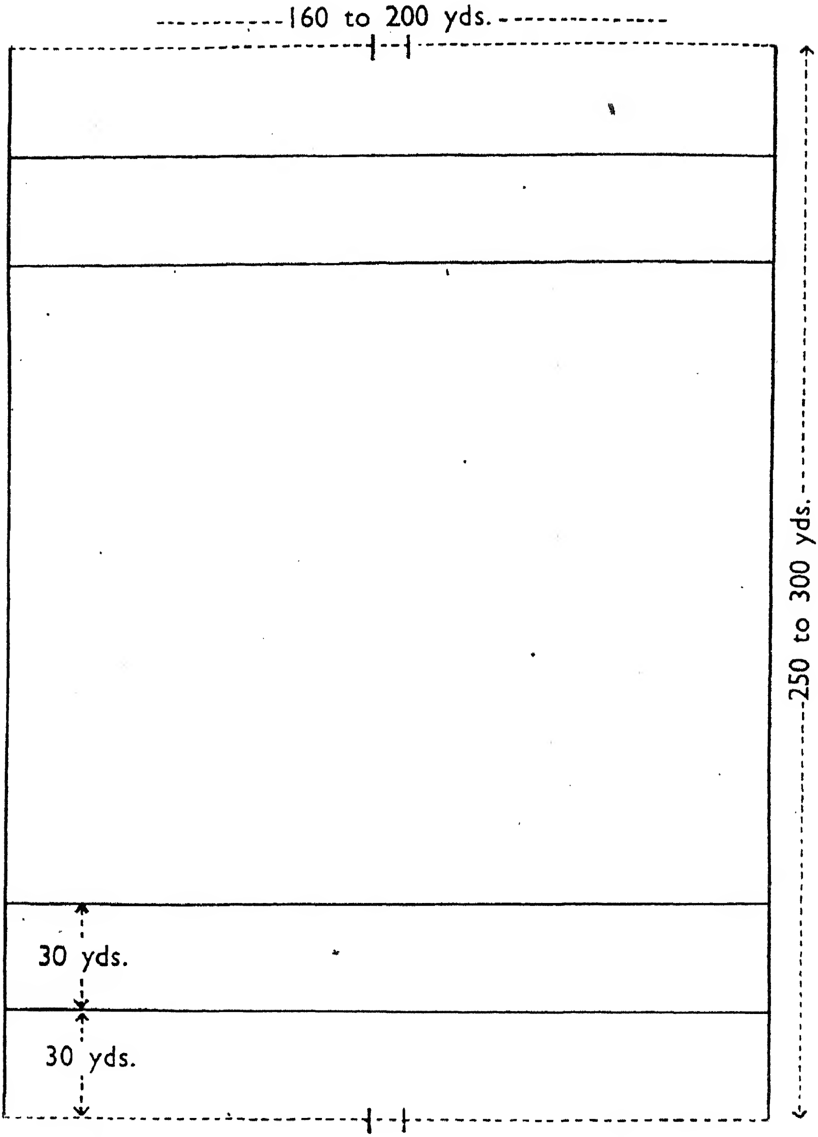
NET.—Height 3 ft. 6 in. at posts, 3 ft. at centre.

Diagram of Ground marked out for Rugby Football



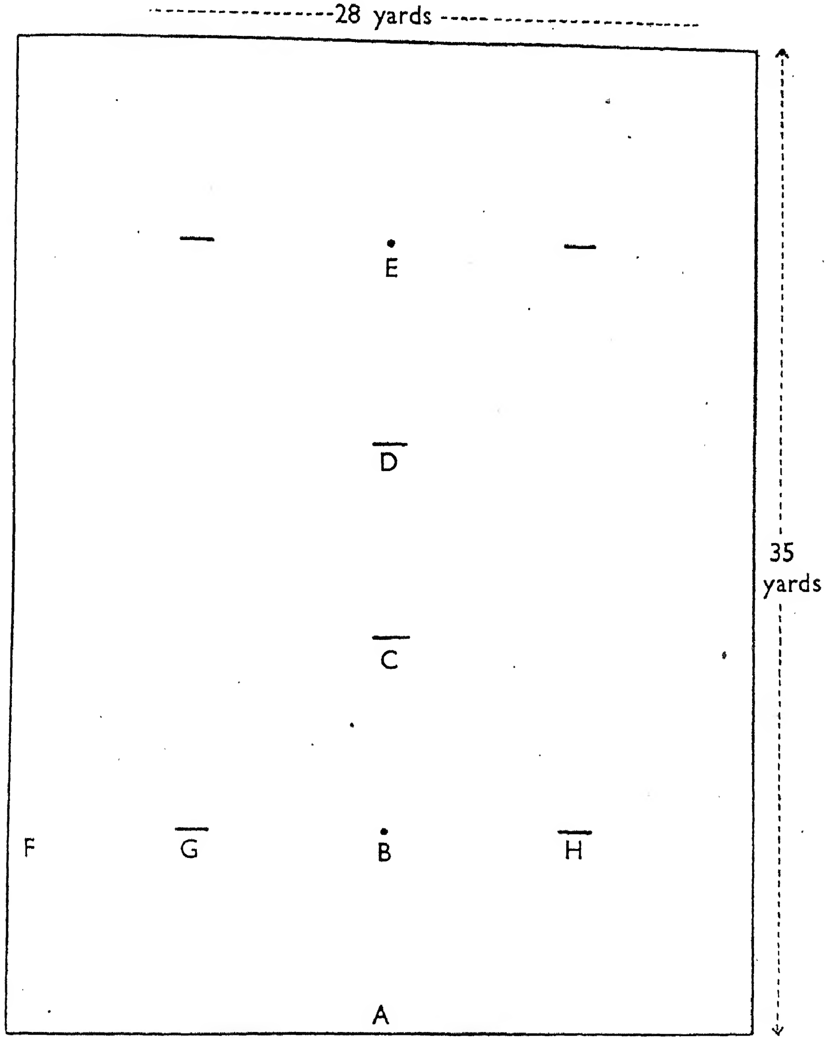
A to B, Goal Line. A to A and B to B, Touch Line.
GOAL POSTS.—Exceeding 11 ft. high. 18 ft. 6 in. apart. Cross bar, 10 ft. from ground.

Diagram of Ground marked out for Polo



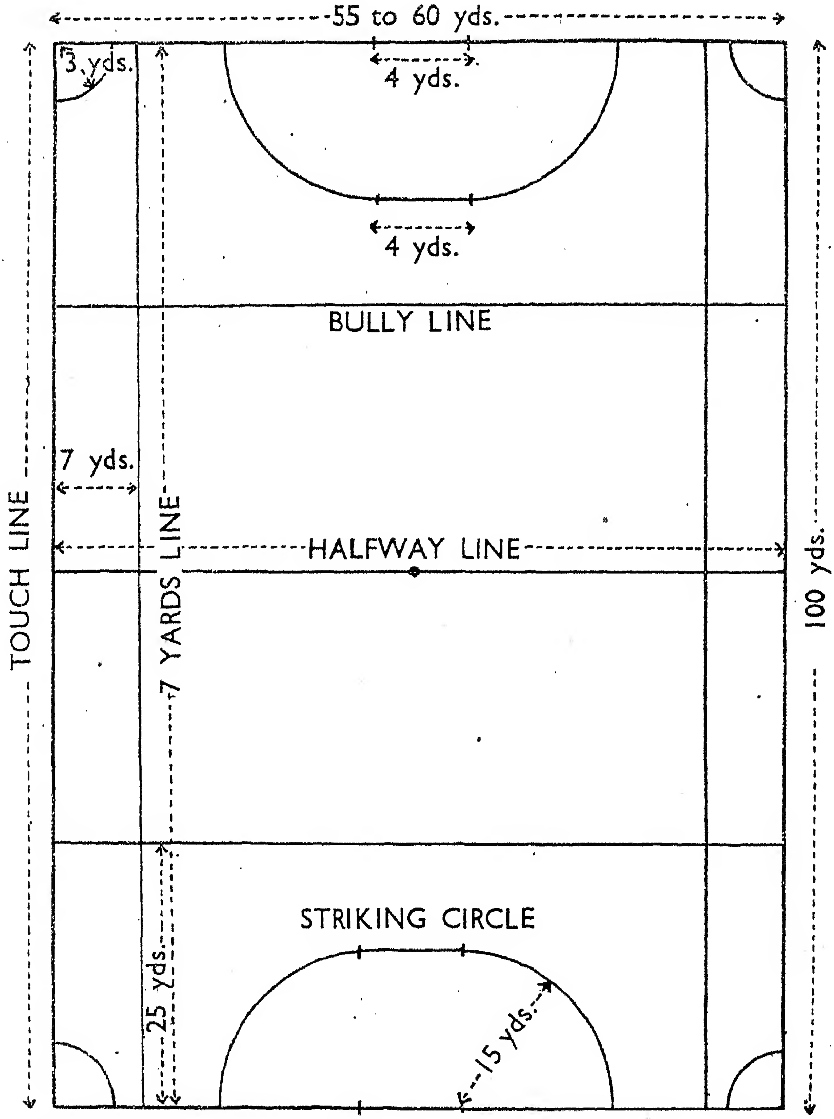
A full-sized ground should not exceed 300 yd. in length by 200 yd. in width, if unboarded; and 300 yd. in length and 160 yd. in width, if boarded. The goals to be not less than 250 yd. apart, and each goal to be 8 yd. wide. The goal posts to be at least 10 ft. high, and light enough to break if players collide with them. The board not to exceed 11 in. in height.

Diagram of Ground marked out for Croquet



A to B, 7 yd.; A to C, 14 yd.; A to D, 21 yd.; A to E, 28 yd.; F to G, 7 yd.
F to B, 14 yd.; F to H, 21 yd.; — Hoop; • Pegs.

Diagram of Ground marked out for Hockey



GROUND.—100 yd. by 55 to 60 yd.
OPENING OF GOAL.—7 ft. by 12 ft.

Diagram of portion of a Bowling Green

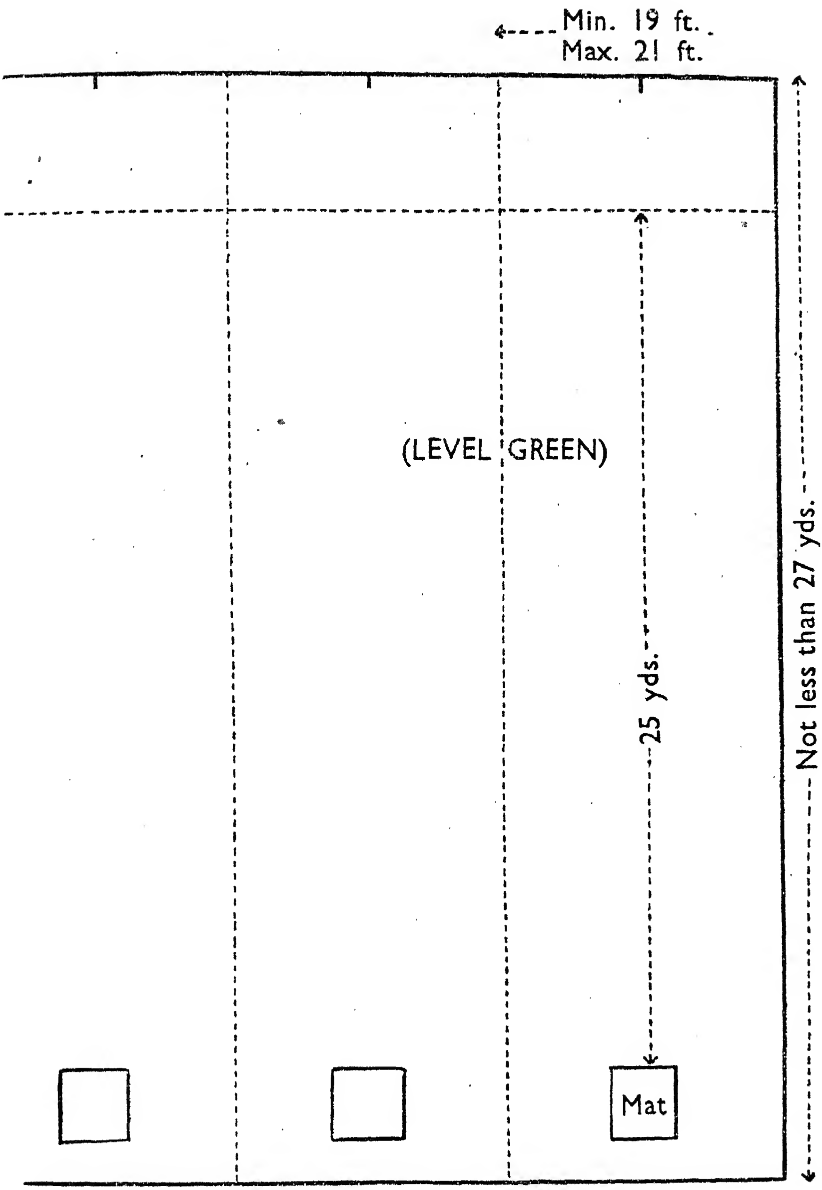
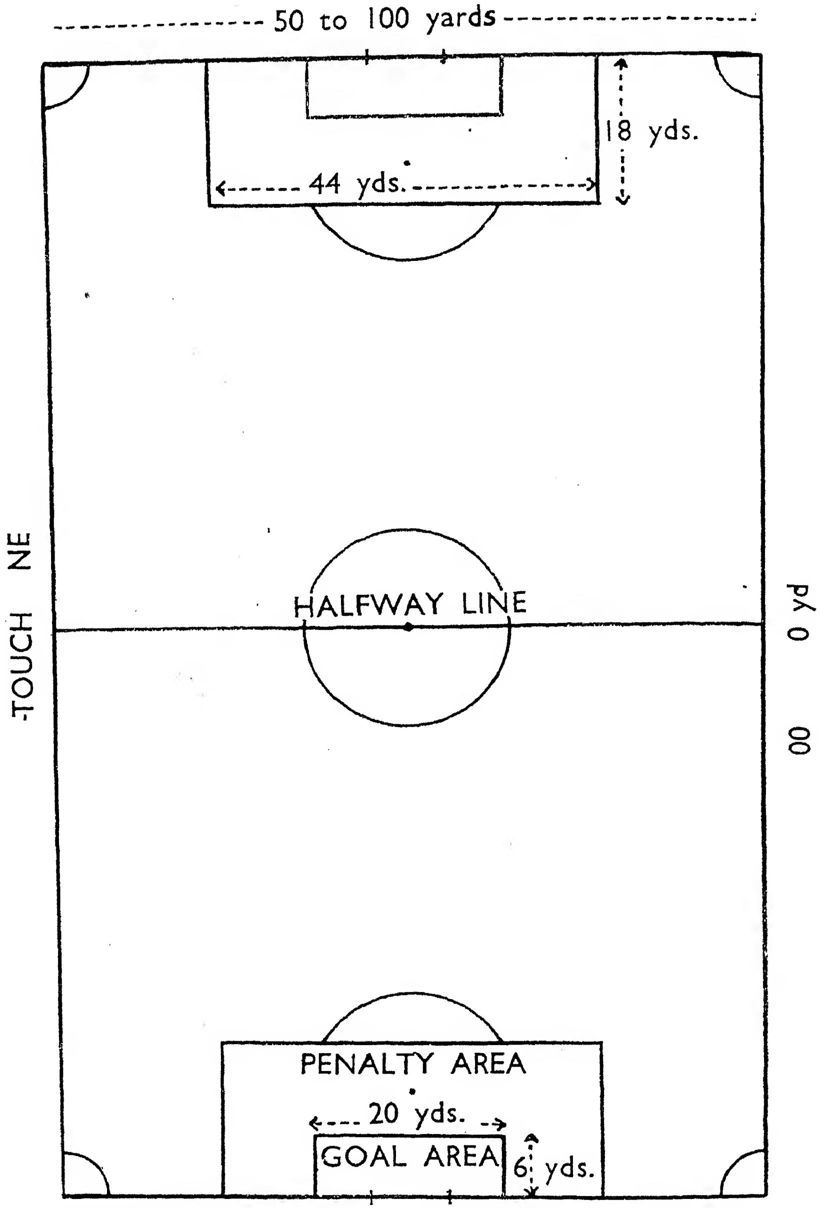
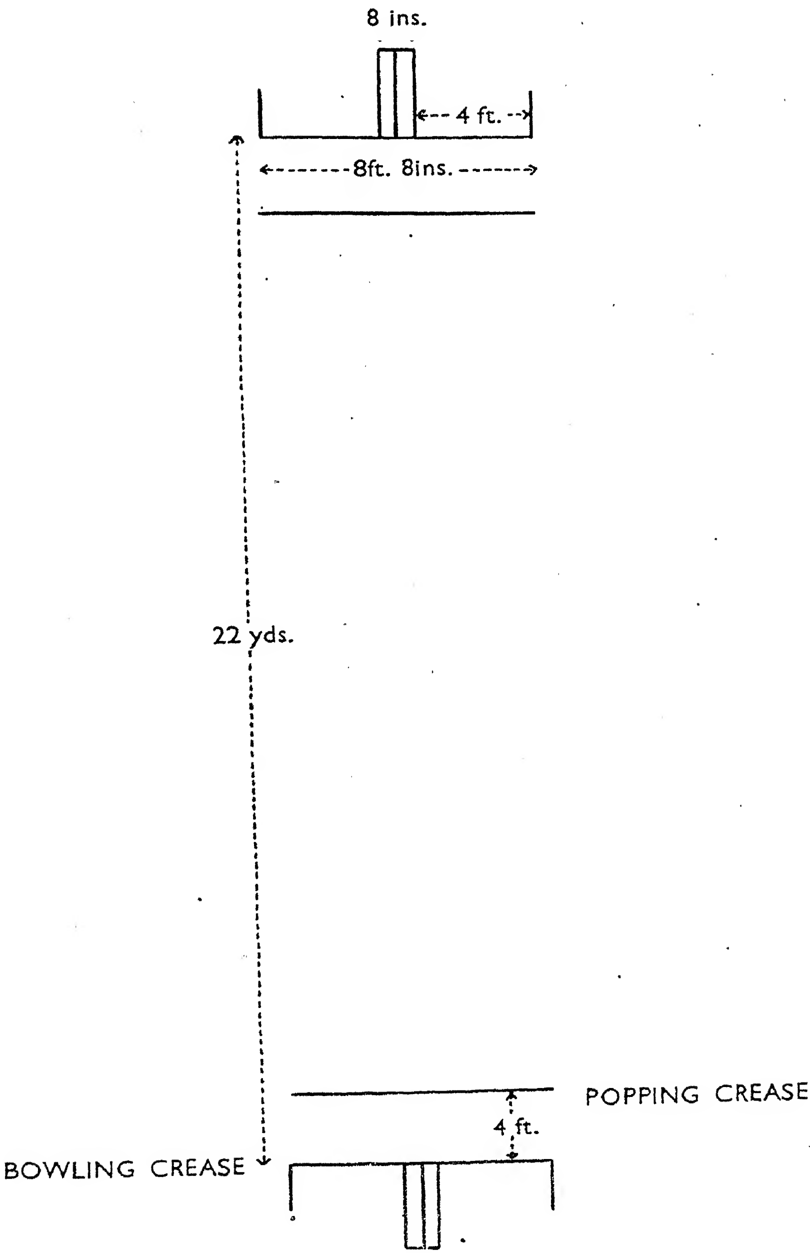


Diagram of Ground marked out for Association Football



GOAL POSTS.—8 yd. apart. Cross-bar, 8 ft. from ground.
PENALTY-KICK MARK.—Opposite centre of goal; 12 yd. from goal line. Arc of circle with radius of 10 yd. from penalty spot to be marked outside penalty area.
CORNERS.—Flag with staff not less than 5 ft. high.
KICK-OFF CIRCLE.—Centre of ground, radius 10 yd.

Diagram of Ground marked out for Cricket



APPENDIX FIVE

Adjustment and Maintenance of Mowers

The object of the following notes is to help the gardener or greenkeeper to deal with those minor faults that may ultimately lead to serious breakdown. In any case a faulty mowing machine cannot give the best results on the tuft. Adjustment is largely a matter of common sense and most high-class machines rarely develop major faults; even cheaper machines have a long life and will withstand a surprising amount of ill-usage. With the better machines (both hand and motor) Instruction Books are issued by the makers and should be closely followed. These contain lubrication charts and lists of spares. Major repairs are best done by the experienced mechanics of the maker or his agents.

Care after use and Storage. In dry weather brush down with a hard broom; in wet weather wash down using a hose. Immediately oil cutting edges using a paint brush, lubricate where required and put away under cover. Don't leave clippings in the box. When storing over the winter choose a dry shed and stand the mower on boards after thoroughly cleaning, oiling and lubricating. Ease cutting cylinder off fixed blade and smear all cutting edges with grease. Clean and grease grass box. Remove driving chains from motor mowers and store in oil. Drain engine crank case with a view to refilling with clean oil at the beginning of the season.

Winter Work on the Mower. Thoroughly clean up hand mowers removing grass from gears and other parts, re-paint where necessary. On motors dismantle and clean carburettor and exhaust system, decarbonize engine and grind in valves, check tension on chains, paint-frames and boxes. Examine all moving parts, including clutch and control cable, for wear and tear. If repairs are needed get mowers away to repair depot early in the winter.

ADJUSTMENT OF HAND MOWERS

(*a*) **Side Wheel Mowers** (*see Fig. 34*): There are two types, those in which the cutting cylinder is driven by a set of gears and those in

which the cutting cylinder is driven by cogs cast on the inside of the wheel acting on pawls and pinion on the cylinder spindle. Access is easily obtained by removing the split pin or unscrewing locking nut. Remove all grass clippings which tend to bind the gears. Regular lubrication of cogs and bearings as well as the pawls or free wheels is important. Adjustment of height of cutting is easily carried out by raising or lowering the back roller. Check height of cut on both sides of bottom blade with straight edge across roller and wheels. The fixed blade is adjusted by screws or hand wheel according to make. Only very gradual movement of screws is necessary. Test cutting by means of paper. If the blades are just touching the bottom blade, yet fail to cut, the cylinder has become dull and should be ground in. If the bottom blade is kinked or bent by accident, it may sometimes be cured on the grindstone but on the whole it is better to fit a new one. Occasionally the whole frame of the mower becomes strained and here return to the maker is essential.

(*b*) **Roller Mowers** (*see Fig. 35*): There is much variation in the details of design in roller machines and there are varying degrees of precision. All the better machines are ball bearing, and transmission is usually by speeding up gears, but sometimes there is a chain drive. Cutting speed is higher than on side wheel mowers and free wheel is usually of the cycle type. Attend to lubrication carefully and see that the gear case is packed with grease. Height of cut is adjusted by one or two knobs, raising or lowering the front roller. Where there is only one knob, check both ends of the blade, using a straight edge, to see that there is strict parellelism. If out of line set the alignment of the front roller by the compensating screw. Setting of the bottom blade is by hand wheel or adjusting screws. In some machines the spring below the bearing housing closes up and there is danger of breaking the casting unless the spring is shortened. In cheaper machines the blade and concave may be in one piece with a central handle for adjusting. In setting the bottom blade it is important that it should be clear of the ground otherwise it may be knocked up against the cutting cylinder. Further, if too close to the ground the bottom blade tends to tear the turf on lumps and ridges. The height of set can easily be tested with a straight edge. Play on the front roller should be eliminated by the adjustment screws fitted, or by a new replacement. Careful attention to grinding-in and lubrication are important.

(*c*) **Grinding-in** (*see Fig. 36*): If the mower will not cut a piece of paper or a leaf cleanly at any point on the length of the cutting cylinder without undue pressure, then the blades are dull. In this condition they will only bruise the grass, leaving a ragged finish and

at this stage grinding-in is necessary. The first step is to adjust the cylinder so that it only just touches the bottom blade. The blades should then be painted with oil and emery and the cylinder revolved in the opposite direction (i.e. anti-clockwise). A special stand may be bought for roller machines and a handle to screw into the main gear wheel. In the case of side wheel machines this turning is done by inserting a stick between the spokes and revolving the wheels in the reverse direction, after turning over the pawl. Light pressure only is required and as the grinding proceeds the cutters are adjusted to the blades. They should be examined to see that they are touching throughout their length. Motor mowers are ground in the same way.

ADJUSTMENT OF MOTOR MOWERS

(*a*) **Transmission and Cutters.** The bottom blade in motor mowers is usually adjusted on the same system as hand mowers; the operation must be done very carefully and a little at a time until the cutting cylinder just brushes the bottom blade. Grinding-in is done as for hand machines though most owners of motor mowers will have this done by the service depot. Height of cut is adjusted by movement of front roller. Attention must at times be paid to the clutch; the lining of which beds down. The clearance between the collar and the operating mechanism is reduced but there is a simple adjustment for correcting this. The conveyor or concave plate designed to throw the grass into the box occasionally requires adjusting. Driving chains are apt to work slack on motor mowers through constant use. In some machines this is taken up by sliding the whole engine forward and in others there are chain tensioners to take up the slack. Chains should not be made *too* tight but should be left with a slight slackness.

(*b*) **Lubrication.** The bulk of motor mowers used on lawns are of the 2-stroke variety. Lubrication of piston and bearings is done by the oil mixed with the petrol. When running in a new motor more oil is needed than later in its life. With 4-stroke engines lubrication is by splash or by an oil circulating system. Oiling instructions are issued with new motor mowers and regular attention to all moving parts is the best insurance against excessive wear and tear. All ball bearings need attention as well as the moving parts on the clutch and the starter and driving chain. Front rollers require careful attention as being in close contact with the ground they revolve at high speed and are soiled frequently with earth.

(*c*) **Engine.** The modern power unit is designed for reliability and trouble free use. Often a few minor adjustments will keep the machine going but larger repairs are best left to the mechanic.

When filling the tank always pour the petrol through a fine strainer. Regularly check over nuts and bolts as they are liable to shake loose and possibly lead to cutter damage.

Starting of a motor mower is simple if the following procedure is adopted—turn on petrol tap and slightly flood carburettor ; if starting from cold close the choke, partly open the throttle, depress kick starter or pull out the starting belt. If difficulty is experienced various throttle widths may be tried.

If there is still failure probably petrol and oil have accumulated in the crank case, this should be drained since this condition causes wetting of plugs and sooting up. If there is further difficulty in starting, the plugs should be removed, dismantled and electrode cleaned. Plug points should be checked leaving a gap of 0·02 in., that is about the thickness of a visiting card. Petrol pipes should be checked for chokages and flexible joints examined as perishing may have occurred.

Other failures to start may be due to the petrol jet or filter being choked. Popping in the carburettor is a sign of choked pipe, jets or filter. Another cause of refusal is faulty ignition and, after cleaning, the dry plug may be tested by placing it on an unpainted part of the engine. On turning the starter sharply sparks should be seen. If sparks are not seen a new plug should be fitted and re-tested and if this fails probably the magneto is at fault.

The contact breaker should be examined periodically and any dirty deposit removed. Should the cam appear dry a single spot of thin oil should be applied to the surface on which the tappet runs as this will prevent rust and wear. Excessive oil causes mis-firing. The usual setting of contact points is 0·015 in. Sometimes failure to start is due to a short circuit caused by insulation on the cable having perished.

At other times the machine will work satisfactorily for a time when after a few preliminary mis-fires it will stop; this may be due to lack of fuel, to faulty ignition, to hot bearings due to insufficient oil, to over-loading, or to dirt under the jets. There are times also when a machine may be giving a poor response to the work. This may be due to poor compression due to loose carbon under the valves, leaking or sticking valves, or possibly leaking piston rings. A knocking sound in the engine may be caused by over-loading, carbon deposit on piston top and cylinder head, or slack connecting bearing, or the mixture may be too hot. The above faults and failures are best put right by an experienced mechanic.

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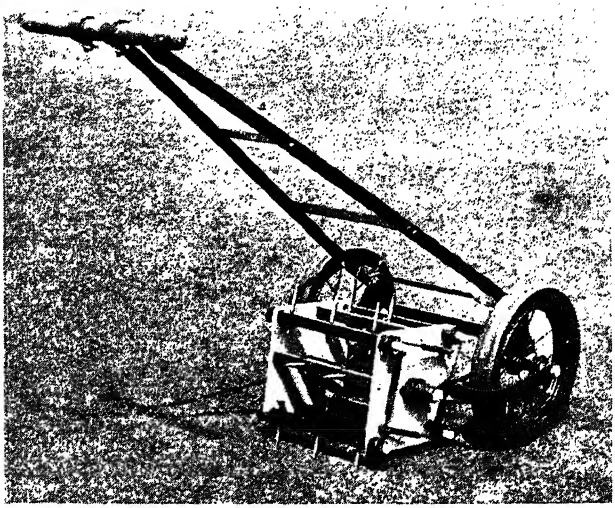

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POST-WAR
RESTORATION
After five years unavoidable neglect, grass lawns and greens will call for careful nursing back to pre-war healthy sheen and well-groomed surface. Plant Protection Ltd. look forward to the time when they can once more make available their experienced advice on lawncraft and their reliable products for lawn cultivation and upkeep.
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